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Guide to community heating and CHP
Commercial, public and domestic applications

FOREWORD

The development or refurbishment of community heating (CH) schemes offers significant opportunities for supplying affordable warmth to residents, for delivering energy efficiently to a wide range of clients, and reducing carbon dioxide (CO_2) emissions. This Guide is a fully revised version of the 'Guide to the Implementation of CHP/DH Systems' (1990).

This new Guide has been assembled by a group of experts directly involved in CH schemes in the UK and other European countries. It provides a full update on all the technical issues that must be addressed by those considering implementing community heating, including feasibility, design, operation, surveillance, and maintenance. CH schemes are capital intensive, so the Guide also suggests financing routes for establishing a scheme. Equally importantly, it also includes new sections covering legal, insurance and environmental matters.

The introduction or improvement of a community heating scheme incorporating CHP provides a unique opportunity to supply heat and electricity directly to domestic, institutional, commercial, and industrial buildings. It is an extremely flexible energy supply system because any fuel can be used, and production from a variety of plants can be utilised in the same network; this is important in providing the most robust of fuel scenarios for the future. Furthermore, together with bulk purchasing of fuel and load diversification, this leads to economical running costs.

Community heating systems are excellent candidates for CHP. CHP can significantly reduce the primary energy use per unit of energy consumed by the final user, with consequent reductions in CO_2 emissions. They also offer a reliable and economic way for local authorities and housing associations to ensure affordable warmth for residents. Effective and economic modern systems in Scandinavia, the Netherlands and Germany are testament to the popularity and environmental benefits of state-of-the-art CH technology that is now available. There are also impressive examples of new and refurbished systems within the UK that are serving the best interests of both their customers and the environment. The Guide recommends that those who are considering, or are about to embark on, a CH scheme should consult operators who have experience of similar schemes. Drawing from such experience at the earliest stage will assist in the initial design. It will also help to ensure that the very wide range of issues that need to be addressed are given proper consideration.

Potential major new schemes can take inspiration from the city-wide networks in Sheffield and Nottingham. Sheffield's network serves 3500 dwellings and other major clients such as Barclays Bank, the Fountain Precinct, and Sheffield's universities, and it is growing — Weston Park Hospital is an example of a major client recently connected. Nottingham's city-wide scheme was exhibiting many of the problems associated with older community heating schemes, before its recent refurbishment took place. Removal or refurbishment of major infrastructure represents a key strategic decision, and it is absolutely vital that such an important decision is underscored by a full option appraisal with full life-cycle costing. When Nottingham carried out such an appraisal it became

clear that the most economic solution was refurbishment of the existing system. Confidence in new pipe technology, monitoring, surveillance, and billing techniques, plus an innovative approach to customer relations, has been rewarded by a system that reliably supplies affordable warmth to residents and other customers.

Community heating schemes are not limited to major cities: Chesterfield, Rotherham, Doncaster, Billingham, Mansfield and Woking are examples of towns with successful smaller schemes. Nor are they limited to local authorities — effective and economical schemes by St Pancras Housing Association and North British Housing Association are examples of the innovative approach pursued by a number of Housing Associations. The Guide covers the issues relating to large schemes (typically several megawatts upwards), but much of it will be essential to those implementing smaller schemes.

Networks can also be configured to supply cooling as well as heating. For example, Southampton's city centre network serves hotels, supermarkets, BBC studios, and a shopping and leisure complex with both heat and chilled water.

The large CHP/CH developments in Europe have been built up by the amalgamation of smaller schemes, often developed initially with boiler plant which may be relocated to new areas at a later date. A similar approach is likely in the UK; Leicester City Council has, for instance, installed small-scale CHP units into tower blocks, creating islands of CH for future linkage. Identification of existing large commercial or institutional buildings and residential group heating schemes will assist the development of a core heat market, provided the building's owners can enter into long-term commitments for the purchase of heat.

The Guide identifies new opportunities to ease the problem of establishing capital-intensive projects such as CH and CHP. Full liberalisation of the electricity market in 1998 facilitates the sale of locally (CHP) generated electricity to residents, so that local authorities, housing associations, or those acting on their behalf, are in a position to offer a suite of energy services.

The Government is actively encouraging the greater use of energy services within the public sector. The increasing delegation of budgets and responsibilities to operational units, the emphasis on the use of the Private Finance Initiative (PFI) and changes in Treasury rules are providing fuller opportunities for the public sector to realise the economic and environmental benefits offered by energy services.

The new Guide aims to provide information for all those who are involved with initiating, extending, or refurbishing a CH scheme.

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INTRODUCTION

Community heating is where a number of buildings or dwellings are heated from a central source. This provides economies of scale and diversification of loads. Together with combined heat and power (CHP) plant, community heating (CH) offers:

- environmental benefits: greatly reduced carbon dioxide (CO_2) emissions arising from the high efficiency of CHP/CH schemes
- affordable heat for residents and other users
- new opportunities for local supply of electricity to residents and other users.

The Department of the Environment, Transport and the Regions (DETR) has commissioned this Guide to update and expand the previous publication 'A Guide to the Implementation of CHP/DH Systems', which was produced by the Combined Heat and Power Association for the (then) Energy Efficiency Office, Department of Energy in 1990.

The Guide has been written by individuals prominent in the development of combined heat and power (CHP) and community heating (CH) in the UK during the last 10 years. The advice given is therefore drawn from those directly involved with successful city-wide CH schemes in the UK, as well as successful smaller initiatives in many other towns and cities. Contributors also include experts from European countries in which community (district) heating is a mature industry.

The Guide includes details of financing, legislation, and insurance, vital to the emergence of successful schemes, and environmental issues are also assessed. Engineering issues, the principal focus of the last Guide, have been fully revised.

The purpose of the Guide is to provide a source of information for all those involved in developing a new scheme, or undertaking major refurbishment of an existing scheme. The Guide does not, however, purport to cover every circumstance; indeed each project which emerges is unique, possessing an individual mix of technical, political, and social requirements. The Guide does aim to comprehensively signpost the wide range of issues which need to be addressed.

The target audience is therefore wide, encompassing local authorities, housing associations, developers, suppliers, consultants, lawyers, and financiers. The Guide covers the main issues that need to be taken into account, and makes reference to other guidance documents and standard texts.

The information provided spans the evolution of a scheme from inception through to day-to-day running, and it also embraces planning, engineering and commercial aspects; further material is collected in a series of appendices for reference. It applies to:

- new schemes being planned
- existing schemes requiring improvement
- existing schemes being extended.

Comprehensive information is presented for larger networks (typically from several megawatts upwards) but much of the information is essential for smaller schemes. Smaller schemes could comprise a group of as little as 60 dwellings or even less, all heated from a single source.

This Guide aims to assist all those who are involved with community heating schemes:

- local authority, housing association, housing action trust personnel
- housing professionals involved with housing regeneration
- utilities
- energy management contractors
- architects and developers.

The Guide is set out as follows.

Section 1, ‘Feasibility studies’, discusses the principal issues which will determine whether or not a scheme is viable. This includes looking at heat demand assessments, potential revenues, and a strategy for development, as well as deciding on actual plant.
Section 2, ‘Implementation’, is concerned with setting up the scheme and ensuring it remains financially viable. It therefore covers marketing, financing, and the options for selling heat (and electricity) to customers.
Section 3, ‘Design and engineering’, is divided into two parts:

- Part A, ‘System design’, describes the community heating network as a whole; it is concerned with devising a system which is optimised, but which also has future expansion in mind
- Part B, ‘Component design’, concentrates on the items of plant that may be selected, primarily CHP, and also includes aspects of the mains and the interface between mains and customers.

Section 4, ‘Operation and maintenance’, outlines the principal operational and maintenance issues and procedures. It deals with moisture detection methods, and covers in some detail the procedures which ensure proper water treatment.
Section 5, ‘References, current standards and codes of practice’, is a compilation of important texts, and relevant regulations and standards which must be adhered to.
It is vital that the correct legal, environmental, insurance, and health and safety expertise is sought when a community heating scheme is being developed. The principal issues are assembled in the appendices.
Appendix 1 covers the legislative framework
Appendix 2 brings together environmental matters
Appendix 3 lists necessary insurance considerations
Appendix 4 deals with health and safety issues
Appendix 5 covers life-cycle costing.

FEASIBILITY STUDIES 1

1.1 INTRODUCTION

This section provides guidance on the typical elements of a feasibility study and the factors that need to be considered. Any CH development, whether new or refurbished, large or small, should start with a feasibility study, during which the technical and economic viability of community heating, compared with other possible options, will clearly emerge. The application of CHP enhances the CH option by providing heat and power with a very high overall efficiency, so this section deals primarily with the feasibility of CHP/CH schemes. Options should be compared using sound economic principles, always ensuring that full life-cycle costing (appendix 5) is used.
The content of the feasibility study will be far reaching and, in the course of the work, many fundamental decisions will be made as to the technical approach and the most attractive option to be pursued. Once the project development stage is reached it is much more difficult to change course. Consequently the feasibility study needs to be carefully procured, managed and fully discussed before proceeding further.

1.2 DEFINING THE BRIEF

Whether the study is being carried out in-house or using external resources, it is necessary to define a brief. This must state the objectives clearly, and provide information on existing buildings and their heating systems, the general aspirations of the organisation commissioning the study, and the time-scale for the study. Any

particular issues of concern should be mentioned, but otherwise the brief should not constrain the scope of the study.

If external consultants are to be appointed, their selection should be primarily on the basis of the capability, qualifications and experience of the study team and their approach and methodology rather than solely on their fee. The study should include engineering, economics, environmental and commercial issues, together with related health and safety matters, for which a comprehensive team of experts needs to be assembled, often with external consultants working closely with in-house lead personnel.

An indication of the economic parameters to be used in assessing options should be provided in the brief, eg the test discount rate and the period of analysis to be assumed in a discounted cash flow analysis. Such information will be needed during the study, and early discussion and agreement on these parameters is advisable. It is important to insist that the correct basis of full life-cycle costing is applied to each of the options under consideration.

Once the main options have been established, capital costs will need to be estimated, as well as operating and maintenance costs where these are the responsibility of the CHP/CH developer.

1.3 HEAT AND ELECTRICITY DEMAND ASSESSMENTS

The starting point of a study is the determination of the market for heat, cooling and power. Initially, this involves enlisting or conjecturing support for a scheme from organisations such as the local authority, large hospitals or a university, all of which can help to provide essential core load for a proposed scheme. It is also important to consider the concentration of heat demand which can accrue from such potential customers. Cooling by means of absorption chillers offers a further use for heat, particularly at times when heating is not required.

The heat, cooling and power requirement for buildings can be obtained from historical data, provided the existing building use is to remain unchanged, or by energy modelling techniques if new buildings or changes in use or occupancy are envisaged. It is important that all cost-effective energy-saving measures for the building either be implemented, or at least considered, before determining heat demand. The fundamental minimum requirements of the heat demand assessments are:

- the temperature requirements of the heating system
- the determination of peak heat demands
- annual energy consumption.

These data will enable some approximate economic work to commence. However, the revenues from the production of electricity vary markedly with time of day and time of year, and hence the cost of heat production from a CHP plant will also vary over the year. It will, therefore, be necessary to determine a heat demand profile over the year, at least on a monthly basis and preferably weekly.

Monthly heat demand profiles can be estimated using weather data, together with establishing a hot water energy demand profile.

In addition, the variation of heat demands over a 24-hour period will be useful, but these data are likely to be available only if a high level of instrumentation has already been installed within the buildings. The hourly heat demand profile is required so that simultaneous heat and power production can be simulated.

For electricity, half-hourly data will normally be available for larger users, and monthly data from bills.

Consideration needs to be given to the effect of the following on demand profiles for heat and power:

- metering and charging tariffs — if historical data are based on unmetered heat a change to metered supply normally leads to significant reductions in heat use
- there may be cost-effective opportunities to reduce heat demand by adding insulation to the building fabric
- liberalisation of the electricity market (in 1998) makes it easier to sell electricity directly to residents on community heating schemes
- use of surplus heat for cooling, particularly in summer, when residential heating requirements are low or zero.

At the feasibility stage these decisions will not have been finalised and it may therefore be necessary to proceed with a range of possible heat and power demands.

1.4 HEATING SYSTEMS WITHIN BUILDINGS

It is necessary to establish details of existing heating systems within the buildings. Some of these may be unsuitable for connection to CH systems, in which case an outline engineering design will be needed for their replacement. Where systems are more compatible, their operating temperatures and pressures need to be established together with an assessment of their effectiveness in meeting current and future needs. If there is some spare capacity available then it may be possible to reduce operating temperatures and/or flow rates in heating circuits, which will generally be of benefit to the CH scheme. It is also important to establish the method of control used for both time and temperature in order to predict accurately effects on the CH system.

When details of existing systems are available it will be possible to propose a programme of works that will enhance existing systems and yet still be compatible with the proposed CH system. However, several options may have to be considered and cost estimates prepared for use in an overall option appraisal (see section 1.7).

In some buildings, the provision of domestic hot water may represent a significant part of the demand, and there are a number of ways of generating domestic hot water from a CH system. The most energy-efficient schemes will involve taking advantage of the low temperature of the cold water feed so as to cool the community heating return as close as possible to this temperature. This leads to the use of non-storage calorifiers or additional coil surface in cylinders. In larger buildings, two-stage heating, utilising the return water from a space-heating circuit to carry out preheating of the cold feed, is the best solution, provided it is economical.

1.5 CENTRAL PLANT

Once the heat demand assessment has been made, work can commence on examining the central plant options. The aspects to be covered are:

- prime mover choice
- fuel choice, contract flexibility, and security
- site location and topography, and interfaces with fuel, electricity and CH infrastructure
- balance between CHP heat and boiler heat
- provision of standby capacity
- building to house the plant
- ancillary plant.

It is likely that a number of options will present themselves and each will need to be analysed under similar assumptions to determine the optimum selection. Capital, operating and maintenance costs will need to be assessed for each combination of plant.

The CHP operating strategy needs to be developed to establish the most economical method of operation in relation to varying heat and power demand profiles and varying selling prices, eg following the heat demand or operating at full output and dumping heat. A spreadsheet-based operating model is essential to ensure that the correct operating strategy has been made and to calculate the annual energy flows, and to permit rapid sensitivity analysis.

The optimum CHP plant capacity needs to be determined by considering a range of plant sizes and by carrying out an economic assessment of each.

For single-site CHP projects it is important to have a reasonable match between the generated output and the electricity demand. For a CHP/CH system, electricity is often sold in bulk and the site demand must also be taken into account. However, there may be good opportunities for selling electricity to customers who are more directly linked to the scheme, by ‘use of system’ arrangements for example. In this case, sizing the CHP plant in relation to electricity demand may need to be considered. The use of thermal storage and heat dumping may be of assistance in allowing the CHP plant a greater flexibility in matching demand profiles. There may also be opportunities for tri-generation (heat, chilling and electricity).

Some CH schemes are initially established without CHP, due to the large capital outlay involved. Even without CHP, there may still be environmental and economic advantages from load diversification, and further economic benefits from purchasing fuel in bulk. The use of pre-insulated pipes and low NO_X high-efficiency or condensing boilers have helped to make modern CH systems robust, environmentally friendly, and economically advantageous. It should be stressed, however, that CHP offers immediate environmental benefits, and long-term economic advantages. Finance routes to mitigate the problem of procuring capital-intensive plant are set out in section 2.

1.6 HEAT DISTRIBUTION SYSTEMS

After the building demands and the central plant location have been determined it is then possible to examine the heat distribution system. In order to analyse the network rapidly and to calculate costs, dedicated computer software is essential. For large schemes, only the primary mains, together with sample areas of sub-distribution mains, will need to be analysed at this stage. The more difficult aspect is to determine which routes for CH pipework are technically feasible and cost-effective. Considerable assistance may be obtained by consulting Ordnance Survey maps at 1:1250 scale. These are now available on CAD format but at a significant cost. However, there is no substitute for an informed site survey, and a detailed examination of other utility services drawings. Within the feasibility study it will be necessary at least to identify any major constraints to routes, eg road and rail crossings, the presence of underground sewers, railway tunnels, etc. In selecting routes the use of open, grassed areas will lead to significant cost savings, as will the avoidance of major roads. Consultation with the Local Authority Planning and Highways Department is essential.

1.7 OPTIMISATION

This is the most complex phase of a feasibility study, where the various options available for CHP (or other) plant, heat distribution and building heating systems need to be assembled into a number of scheme options — all with their individual sets of cost and revenue streams. Some cases may be simplified by a process of logical comparison, but normally it will be necessary to compare the options using discounted cash flow analysis, and hence to determine the preferred option on the basis of maximising net

present value or internal rate of return (see section 1.10).
Some of the system optimisation issues that are likely to need evaluation are given below.

Operating temperatures

A high flow temperature will result in a larger temperature drop, lower flow rates and hence smaller pipe diameters can be used. This capital cost advantage will be offset by the need for more expensive building connections and possibly higher heat production costs, depending on the CHP plant selected.

Operating pressures

The option exists to run the system at a lower operating pressure by over-sizing the network; the extra cost incurred should be compared with savings from using the cheaper direct connection method to link building heating systems to the community heating network. Pumping costs also need to be considered, particularly for larger systems, where higher design pressure reduces the amount of booster pumping required. The topographic variation will also need to be considered when deciding upon operation pressure.

Size of scheme

A smaller scheme may be more compact and have a relatively inexpensive network, but larger schemes may result in economies of scale for the CHP (or other) plant arising from higher efficiency and lower capital cost per kW. The phased expansion of the scheme also needs to be considered, as does ways in which this might affect the plant and the network design.

Heat meters

The installation of heat meters will result in lower buildings energy use and reduced operating costs. If the individual dwellings are equipped with heat meters, energy savings should be compared with the additional capital cost and consumer administration charges. It is also possible that the provision of heat meters for each dwelling may be the only way to achieve market acceptability by residents and energy developers. In addition, the inclusion of heat meters will have a positive effect on Standard Assessment Procedure rating (SAP).

Building heating systems

The conversion of a heating system to more compatible operating conditions will involve additional capital cost, but if it results in better plant selection or increased heat sales it may be justified. One example is converting steam heating at a hospital to low temperature hot water heating suitable for connection to a community heating network.

Improvements to building fabric

Some building fabric insulation improvements will be cost-effective in energy terms. The economic advantage is not as great when the building is supplied by CHP/CH as it would be for small conventional boilers or electric space heating, because the marginal cost of heat is lower. There is, however, a financial advantage in reducing peak heat demands as the capacity of the CHP plant and the heat distribution network can be reduced. The resultant saving in capital cost needs to be included in the economic assessment of insulation measures.
Further discussion of these issues will be found in section 3.
Once the main options have been established, capital costs will need to be estimated as well as operating and maintenance costs where these are the responsibility of the

CHP/CH developer.

1.8 REVENUES FROM HEAT AND ELECTRICITY SALES

1.8.1 Heat sales

A good understanding of a customer's current and likely future costs for conventional heating is required in order to judge the maximum heat sales income available. These costs will include fuel, operating and maintenance and provision for future boiler replacement.

It will be necessary to structure a heat sales package so that the advantages can clearly be seen. At a feasibility level there will need to be a sufficiently large discount to be confident that this level of income can be obtained for the period of analysis. A long-term commitment is unlikely to be obtained at this stage and information on existing costs may be limited, so a cautious approach may be needed. The situation is clearer in the residential sector where the costs of the conventional individual boiler systems are generally well established.

The main options available in the residential sector are:

- sales to individual residents by means of a fixed charge related to size of dwelling (this arrangement is historically common with some local authorities where costs are pooled for all community heating schemes in the local authority area)
- sales to individual residents based on measuring the heat energy actually used (dwelling heat meters)
- sales to individual residents based on the measurement of actual energy used by a block of flats and an apportionment based on size of dwelling/occupancy (this system is most common on continental schemes with this type of built form).

Prepayment systems can be used to collect either fixed or variable charges or a combination of both. Some consideration should be given to assessing the likely levels of bad debt where prepayment systems are not installed, and bad debt costs may need to be incorporated in the economic analysis.

1.8.2 Electricity sales

Where CHP plant is installed, it is vital to obtain the maximum income from the electricity produced. Typically, a 10% increase in electricity sales will improve the internal rate of return (IRR) of a project (see section 1.10) by 2%, whereas a 10% increase in heat sales will improve the IRR by 1%.

The CHP/CH company may opt to sell electricity in bulk to the host public electricity supplier (PES), which will normally offer terms on a p/kWh basis for electricity generated at different times of the day and year seasonal time of day (STOD) tariff. However, if the CHP/CH company can supply electricity users directly (this may include residents themselves) a much better return can be obtained. Among the more favourable options that exist (following the liberalisation of the electricity market in 1998) is the sale of electricity direct to residents and other customers. A summary of the options is as follows:

- sale to the host PES
- sale to a second tier supplier, ie other PESs and other suppliers of electricity
- direct sale to customers as a second tier supplier. This implies pool membership for an aggregate supply of more than 500 kW

- sale under the non fossil-fuel obligation (NFFO) (only for energy-from-waste projects which have bid for this arrangement in advance).
- sale through the pool (this entails having pool membership and is more appropriate for projects in the range 30 MWe-50 MWe)
- sale as an on-site generator to other customers on the same site.

Further advice is available in ‘Electricity Production Connected to the Local Network: a guide’ published by the Association of Electricity Producers (0171 930 9390).

New Practice Profile 112 and New Practice Report 113 (in preparation) provide further guidance on the direct sale of electricity to residents.

It will normally be helpful to use the conventional route of sale to the host PES for the base case analysis, with the other options considered as possible improvements that can be investigated, depending on the scale of the project and the resources of the study. An element of negotiation will be needed in most of these options. As a result, definite figures are not likely to be available at the feasibility stage and a range of results may be presented as a sensitivity analysis.

The sale of electricity as a second tier supplier may be of particular interest to CHP/CH schemes because there will be the opportunity to market heat and electricity together to customers on the community heating scheme. Selling two utility services may also bring benefits in metering and charging arrangements. This option is therefore discussed further below.

If a CHP/CH scheme is to undertake to sell electricity direct to customers, additional arrangements will be required, for example:

- a top-up and standby purchase arrangement for times when the generation is less than customer demand (including times of CHP plant outage); as a pool member a second tier supplier can purchase this power direct from the pool
- a contract for selling spill power for times when more power is generated than customers demand
- either the payment of use-of-system charges, the purchase of existing electricity infrastructure or the installation of new cables in order to transfer power to the customers.

In the domestic sector, the creditworthiness of customers should be considered and the possible need for a form of prepayment. The management of debt collection is a customer care issue, and disconnection policies need to be fully developed if customers are to be retained in the long term.

1.9 DEVELOPMENT PROGRAMME

An important output from the feasibility study is a development programme. This is required first to permit the construction of cash flows for capital expenditure, and second to enable advance planning of subsequent stages. A separate, more detailed programme may be produced covering the period of development from the conclusion of the feasibility study to the start of construction, if the route to achieve this is sufficiently clear. It is also worth establishing a watching brief on all work involving renewal of underground services, so that opportunities may be taken to coordinate projects, thus reducing costs and disruption.

Issues to consider when drawing up the programme are:

- the need for a further project definition stage
- the need for further site surveys and investigations (noise, air quality, ground conditions, structural surveys, topographical surveys)
- consultation with customers and adjacent building owners and residents
- planning applications (and associated environmental statements)

- Building Regulations applications
- energy rating and emission improvements
- preparation of invitations to tender
- tender period
- short-listing construction companies
- short-listing energy developer companies
- short-listing operating companies
- assessment of tenders and final negotiations of contracts
- mobilisation
- site clearance
- construction*
- commissioning and testing
- operation and maintenance.

*Supervision during construction is of paramount importance in order to secure the necessary quality of system.

1.10 ECONOMIC APPRAISALS

At the heart of any economic appraisal are the cash flows, a set of annual capital, operating and maintenance expenditures, and annual revenues from the sale of heat and electricity. These cash flows are normally evaluated in real terms.

To compare scheme options, and determine whether the project is economically feasible, there are a number of arithmetical calculations based on the cash flows. It is essential that, when conducting an economic appraisal, full life-cycle costs (appendix 5) are used to compare the various options.

Simple payback period

Defined as the period in which the initial investment is recovered by the annual saving. Generally this approach is too simplistic where the capital expenditure may be spread over a number of years, and where the income may vary from year to year. It is therefore not recommended.

Net Present Value (NPV)

To calculate the NPV it is necessary to define the cost of borrowing capital (or lost income from capital which could have been invested elsewhere) and the period for the analysis of the project.

Internal Rate of Return (IRR)

This can be defined as the test discount rate that results in a net present value of zero. IRR is less robust than NPV as it can lead to the selection of a smaller-scale project which, although generating a higher return, involves less capital so that the total value of the income stream is lower than the maximum potential.

Both NPV and IRR calculations are available within most spreadsheet software packages.

The above parameters are normally sufficient to compare options and present the results to the client organisation for a decision to proceed further. An appraisal by a financier is also likely to involve the calculation of tax implications and debt cover ratios (see section 2).

As an illustration of an economic appraisal, two approaches are outlined below.

- *From the perspective of a building owner* who wants to examine the cheapest method of supplying heat and power to the building or groups of buildings (eg a

local authority with a large housing estate). The economic analysis would assemble cash flows for capital and operating costs for both the CHP scheme and the alternative approach of conventional boilers. The CHP scheme would involve significant initial capital and have an income stream for surplus electricity sales. The conventional approach will have investments in future boiler plant scheduled for future years. The NPV approach enables these varying cashflows to be summed to give a single figure; the NPV in this case being the net present cost for supplying the site with heat and power over a defined period. If the CHP/CH option gives a lower cost then it is the more economical option.

- *From the perspective of an energy developer company,* cash flows will be established for capital investments and income from both heat and electricity sales. The heat and electricity selling prices will be related to the market for these energy products. An IRR can be calculated for the project investment and the NPV (in this case a positive number) for a given discount rate. The CHP/CH option with the highest NPV will be selected and the IRR must be greater than the minimum required by the energy developer company, taking account of the risks in the project.

Good Practice Guide 165 gives further information on financial methods. It is worthwhile investigating whether any local major consumer, such as a local authority, is willing to connect all their buildings to a scheme. This can reduce the investment risk significantly and improve cash flow.

The question of economic viability cannot be separated from an analysis of risk, particularly where project finance is the route employed. It will be necessary to carry out an analysis in which as many of the costs and performance figures as possible can be contractually underwritten before presenting the results to a financial institution for a view on financial viability (for more details see section 2). A sensitivity analysis is of assistance in identifying which of the many parameters are the most important when considering the risk to the economic performance of the scheme, and also for indicating the range of likely outcomes. From this analysis the advantages of obtaining longer-term fuel purchase contracts or heat and power sales contracts can be judged.

Some community heating schemes are initially established without CHP, due to the large capital outlay involved. Finance routes to mitigate the problem of capital intensive plant are set out in section 2. It may, however, be instructive to consider the economics of a boiler-only community heating option so that the benefits of the CHP plant itself can be separately demonstrated.

1.11 ENVIRONMENTAL ASSESSMENTS

A preliminary environmental assessment should form part of the feasibility study, identifying both the advantages and disadvantages of CHP. These matters are discussed in detail in appendix 2.

1.12 HEALTH AND SAFETY

Any construction project is covered by the Construction Design and Management (CDM) regulations. The aim of these regulations is to ensure that safety issues are considered from the start of the project, and this may include the feasibility stage. It will be necessary to appoint a planning supervisor and to carry out an outline design risk assessment. Construction and operational health and safety matters are discussed further in appendix 4.

IMPLEMENTATION 2

Large community heating schemes require significant effort in order to enrol, maintain, and methodically extend the customer base; section 2.1 in particular reflects this. Small schemes, which may comprise fewer than 100 dwellings, will still need to consider many of the other issues — such as finance and metering — addressed in this section.
When specifying a small scheme, it is important to bear in mind possible future link-up to larger schemes.

2.1 MARKETING COMMUNITY HEATING

The introduction or improvement of a CH scheme provides a unique opportunity to supply heat directly to domestic, commercial, public and industrial customers. It is also the most flexible energy supply system, since any fuel can be used and production from a variety of plants can be utilised in the same network. This is important in providing the most robust of fuel scenarios for the future.

It is important to deal with a wide range of customers; this will also encourage a healthy load diversification, since different types of customer tend to have distinctive load profiles. It is vital for a new scheme, to enlist substantial initial support. For example, high-density housing (typically local authority, housing associations, or both), city centre commercial zones, hospitals and universities all provide the level of heat demand that can help to initiate and sustain a CH scheme. It is also important, especially for long-term development, to consider expanding schemes to include medium-density to high-density private dwellings, such as pre-1919 housing. Typically, there is a large number of such properties close to town and city centres — the Housing Grants and Construction Regeneration Act (1996) contains relevant information.

Marketing methods will need to be tailored to each category of customer — for example, while the local authority or housing association is likely to represent a large number of individual domestic consumers, tenants themselves should be consulted. Tenants will be interested in the provision of reliable and affordable warmth. Commercial clients may be motivated by the acquisition of a green image, as well as there being a demonstrably sound business case.

A CH system delivers heat to its users via a customer connection that includes controls, metering equipment, and a heat exchanger. This interfaces with the building's existing heating and hot water system. The connection of community heating to a building therefore entails minimal changes to the customer's own internal heating and hot water distribution system. It simply replaces the boiler plant.

Experience within the UK indicates initial reluctance by commercial customers to install CH because it is perceived as 'different'. Once connected, however, customers rarely disconnect, as they soon appreciate the considerable financial benefits achieved by this particular energy supply. Customers should be advised that there will be significant and sustainable bottom-line cost savings, and it can be estimated that every £1 saved on energy makes a net profit contribution equivalent to £10 worth of sales — but without the attendant costs of capturing that business (GEC).

Potential commercial customers are likely to have been signatories to the Government's 'Making a Corporate Commitment' campaign (or a successor). This places responsibility for energy matters at senior management and board level, and is designed to fit alongside other board responsibilities such as quality and productivity.

The introduction of CH into buildings will make a significant contribution to the reduction of CO_2 emissions. This also helps to protect building owners from the effects of any future EU carbon tax; environmental issues are likely to have an increasing influence on

decision-making.
Targeting potential customers should be a priority for:

- new developments
- existing buildings with aging plant
- existing buildings with modern plant.

It should be noted, however, that usable existing plant could be used/purchased to provide energy linking between buildings and form part of the community heating supply or backup system.
Potential customers should be made aware of the benefits of community heating, for example:

Competitive and sustainable cost in use

CH plant is operated and maintained to ensure high efficiency, and customers pay only for the heat they use. Long-term contracts (appropriately indexed) can be entered into, giving customers known and predictable energy costs.

Reduced maintenance/operating costs

The simplicity of the consumer connection ensures minimal maintenance and operational costs; compared with conventional heating systems, savings of 60% can easily be achieved.

No capital expenditure or boiler replacement

The simplicity of the consumer connection avoids capital expenditure on replacing boiler plant. In addition, a CH connection will have a considerably increased life compared to boiler plant.

Safe and reliable operation

Experience of existing schemes in the UK (Sheffield, Nottingham) and elsewhere demonstrates the reliability of modern CH schemes. Robust guarantees accompany most long-term service contracts. In addition to the integrity of the distribution network, additional back-up boiler plant ensures security of supply.
Monitoring, maintenance and installation techniques have been developed to ensure a continuous supply. In addition, there is no requirement for the burning/storage of combustible materials within the building.

Conservation of finite fossil fuels

Effective operation of CH plant ensures high efficiency by reducing combustion losses and conserving fossil fuel. Large energy savings can be achieved by using CHP plant, and it may be possible to adopt an element of renewable energy as a fuel source, for example 'waste-to-energy'.

Fuel flexibility

Larger schemes are likely to have several heat sources with different fuels, enabling switches to be made from one fuel to another, depending on how fuel price developments or environmental taxes changing the price relationship.

Energy-efficient and responsive heating

Individual boiler warm-up/cool-down losses are avoided, and heat is always available instantaneously.

Flexible and controllable system

The user has control and flexibility to provide a comfortable environment energy efficiently. Additional heat load as a result of building expansion may be accommodated

with minimum disruption and cost.

System diversity

Plant capacity requirements are reduced as a consequence of load diversity.

Space saving

The heat exchanger station requires as little as 10% of the space requirements of a conventional boiler plant.

2.2 CUSTOMER CARE

This section deals with the issue of customer care during the implementation and operation of CH schemes. This aspect is very important because the success or failure of a scheme will largely depend on the support received from, in particular, domestic customers.

In particular, customer care must be considered during the three stages of the development which are described below.

Conceptual stage

At this stage, customers need to be made aware of the principles of CH together with the benefits to themselves and the wider community. It may be useful at this stage to establish a customer group, made up of customer representatives, to identify and resolve the many questions and issues arising out of the development and installation of a CH scheme. Of particular importance at this stage is the question of how customer interests are to be protected in the future.

Installation stage

Customers should be fully aware of the nature and scope of works to be carried out, both inside and outside their premises. It is important to hold public meetings to explain fully the programme of works and issue a code of practice that outlines procedures for reporting any problems that may occur during the installation phase.

Operational stage

This may be split into two distinct areas of service

— heating equipment, and delivery of heat:

- Clear information, in the form of an instruction booklet, should be issued which explains fully the various components of the customers' internal heating system, how they each work and to whom any faults should be reported. Guarantees in respect of response times for repairs should also be given.

- Customers should be made aware of how heat is delivered to their premises and the responsibilities of the operator of the scheme to ensure that a heating service is continuously available. One particularly useful method for this is the introduction of a customer charter, which should be developed in consultation with the customers. This should cover areas such as:

  — commitment to customers, eg advance warning of planned maintenance; back-up heat sources for domestic customers
  — response to faults
  — connecting to the CH network
  — moving home
  — meter reading
  — method of payment

— strategies for non-payment, eg installation of a card system calibrated to ensure recovery of debt
— disconnection — but only as a last resort
— complaints procedure.

2.3 CHARGING SYSTEMS

Domestic consumers may be charged for the energy used in various ways:

- *Conventional billing*. A monthly, quarterly or annual bill based on actual meter readings.
- *Budget accounts*. An annual account is raised, reconciling actual heat usage according to a heat meter, with budget payments made throughout the heating period, similar to billing procedures used by the gas and electricity utilities. The annual account will either credit or debit the customer accordingly.
- *Prepayment devices*. Consumers pay for heat as needed, rather than by quarterly billing or budget account. Prepayment controllers linked to heat meters reduce administration costs, bad debt, and the need for disconnection. It should, however, be noted that users of prepayment cards pay a little more for their heat. Facilities for emergency credit, dual fuel, multi-tariff, debt recovery, standing charge and minimum temperature may be included. They can be operated by token or credit card, and information can be recorded and recovered manually, by computer, radio or telephone link.
- *Metering and prepayment systems for both heating and electricity*. The liberalisation of the electricity market from 1998 brought with it the opportunity to sell both heat and electricity together to domestic users connected to community heating. Cost benefits can be obtained by combining the meter reading and billing activities into one operation. A number of prepayment technologies are capable of accepting up to three inputs, thus reducing the cost of installing prepayment equipment. A code of practice should be developed in consultation with customers to cover such matters as debt rescheduling and disconnections.

When heat metering is not installed:

- *'flat rate' charging* for heat as part of the rent is usual. Under this system, the heating charge to individual dwellings is based on the number of rooms, total floor area, or other similar criteria, and the overall cost of heating is divided among the dwellings pro rata. Since individual usage has only a small effect on the heating charge, the consumer incentive to conserve heat is reduced, so that flat rate charging is not generally recommended; it should, however, be borne in mind that residents may be less inhibited about using enough heat to keep warm, also ensuring that the building fabric is heated adequately
- *heat allocation* is one approach to the problem of potential customer indifference to saving energy. This method is particularly applicable to low-income families. Sufficient heat is allocated (supplied) to each dwelling in order to maintain an agreed temperature in the dwelling. Similarly, a prescribed quantity of hot water is supplied; an electrically heated boost is available if required, with the electricity consumed paid for in the normal way.

Industrial, public and commercial consumers will be metered, and the meters will help them to identify their base load heat demand, and operating efficiency.

2.3.1 Automatic meter reading systems

Energy consumption and related information recorded by a heat meter can be read either manually or remotely. Various data collection systems are available, including

direct linkage to an independent heat accounting system.

Hard-wired systems

These are either dedicated central panels wired to each meter in the scheme, or a meter 'bus' system where each meter has a unique address supporting both whole-system and individual meter interest. The 'bus' system allows direct downloading of meter information to a central computer for analysis and preparation of accounts. The systems are usually limited to 4 km of cable length, although this can be extended by the use of telephone modems. Building energy management systems (BEMS) may also be used in conjunction with a meter reading system.

Mains-borne systems

These use existing electricity supply cables to enable communication with meters. Until recently, this method was suitable only for use within the boundaries of each particular property. However, systems are now being developed for use over wider areas by arrangement with the cable owners — normally the PES — and the meter operator.

Radio systems

Each meter is fitted with a radio module that 'sleeps' until it receives a 'wake-up call' from the master transmitter. It then transmits its meter reading and sleeps until the next interrogation. Each meter has a unique address. The master transmitter may be hand-held for reading domestic utility meters. In commercial applications it may be controlled by computer and in some cases it may be solar powered. Consideration has to be given to maximum transmission distances between transmitters and receivers. Approval of the radio system frequency and an operating licence are required.

Fibre optic cables

These enable meters or prepayment controllers to be read from outside the dwelling. Cable lengths are restricted.

2.3.2 Metering standards

All metering must comply with the new European standard EN 7234-1: 1997 (see section 5.1).

2.3.3 Operational issues

Installation

All heat metering equipment should be installed in accordance with the manufacturer's specific instructions. Care should be taken to ensure that battery replacement (where fitted) is not overlooked and that secure mains power supplies are provided where appropriate.

Commissioning

Commissioning of heat meters should always be carried out following installation, both to maintain the warranty on the equipment and to ensure the correct installation and functioning of equipment.

Calibration

There is no current UK requirement for calibration checks of meters, once installed. This has led to the wider adoption of solid-state meters due to their proven long-term reliability and accuracy. Generally, the recalibration period for electronic heat meters will be about 10 years, compared to the requirement for mechanical flow meters, which is every five years.

Hydraulic control

Close control is necessary to ensure that the design flow-rate is adhered to throughout the scheme. Effective heating controls are also necessary. Consumer controls provide timed operation of the system, within the design parameters, and maintain individual comfort levels. Controls provide the means, while metering provides the incentive, to use heat responsibly.
Where a flow meter or heat meter displays an instantaneous volume reading, the information can be used to balance the hearing installations accurately through the adjustment of balancing or regulating valves. This is an economical and accurate method of achieving design flow rates to each consumer.

Water quality

Heat meters, particularly flow meters, are affected by water quality, so strict observance of a water treatment regime is important. This minimises the amount of suspended solids, corrosive conditions and deposited salts that may affect the performance and life expectancy of the meter, controls and the system generally.

Maintenance

Regular and controlled planned maintenance of all system and metering equipment is essential.

Security

The heat meter (and prepayment units) should include reliable security features in order to minimise and identify unauthorised interference and reduce any possibility of fraud.

2.4 METERING SYSTEMS

2.4.1 General

The case for metering CH systems is based on the following considerations:

- charges are made for actual usage
- individual accountability helps to reduce energy consumption
- system efficiency can be monitored
- the number of connections can be maximised
- fixed costs can be more readily recovered.

The World Energy Council Report (1991) on district (community) heating states that: ‘practical experience has clearly shown that heat consumption is reduced by 25%-35% when every single end consumer has a meter and pays for heat according to this meter.’
Equipping individual dwellings with heat meters does, however, increase the installation cost of a CH scheme. It is important at the planning stage to account for additional capital cost and administration charges, as well as energy savings. Such an assessment should be part of the full initial option appraisal, which should always be carried out using life-cycle costing. If the available capital does not justify including heat metering from the start, the CH scheme can still proceed, with the system configured to allow for the installation of heat meters later on.

2.4.2 Metering systems

Metering systems fall into two main categories — energy meters, and apportioning devices.

Energy meters

Energy meters measure volume flow rates and flow and return temperatures, integrating this information to provide a reading of true energy consumption.

- *Impeller/turbine meters:* these are widely used, but early designs suffered from dirt and deposits in the system water, gradually losing accuracy due to wear on moving parts. This problem has now been overcome, and latest designs conform to the same standards of accuracy as static meters. These meters often have the same temperature sensors and integrators or energy processors as the solid state meters. It is recommended that the flow unit be recalibrated or replaced every five years.
- *Solid-state meters* (generally electromagnetic or ultrasonic): these have no moving parts and are therefore less susceptible to the effects of dirt in the water than other types of meter, although correct water treatment is obviously important. They are highly accurate even at very low flow rates, require little maintenance, and accuracy can be maintained in line with current UK and European standards. Solid-state meters are more expensive than turbine meters but they do not require recalibration every five years.

Apportioning devices

Although not classified as meters, devices are available that permit an approximate division of usage among consumers. Such devices have been widely used in some European countries. However, accurate and fair apportionment depends on a great number of variables. These include system operating temperature, the extent of fabric refurbishment, and heat loss differences due to physical position. A top floor flat with northerly aspect, which is far from the boiler-house, for instance, is unfavourably located. Although they may still be encountered in existing schemes, apportionment is unpopular in the UK, with accurate heat metering being the preferred choice. Apportioning devices may be found in existing schemes, but it is not recommended that they be retained where there is full scope for refurbishment.

2.4.3 Meter components

An industrial or commercial heat meter is generally made up of three components:

- a flow transducer sized in accordance with the flow rate and operating temperatures of the system
- a pair of matched temperature probes, generally either PT100 or PT500 resistance
- an energy processor or integrator to calculate the heat consumption. This information may be linked to remote reading systems or building energy management systems (BEMS).

Turbine, electromagnetic or ultrasonic flow meters are the most common types. For system operating conditions that exceed the usual operating limits, vortex or orifice plate meters may be used.

Correct selection and sizing of meters is important to meet operating conditions; pipe size does not always determine meter size. Maximum and minimum flow conditions and heat loads need to be known. Some meters have restricted installation positions, which could be a critical factor when selecting a meter.

It is important that, where they are being used as a basis for charging, meters are commissioned following installation, and that the processor and probes are calibrated annually. Maintaining the integrity of the meter installation is vital in commercial and industrial applications where high demand could materially affect the accuracy of heat

accounts.

2.5 HEAT SALES TARIFFS

2.5.1 General

Having decided upon the appropriate form of metering or apportioning system, the tariff can be calculated to generate the required income streams. Within any energy supply operation, there are initial costs, capital finance costs, fixed costs, variable costs, cost of sales and profit to be applied as charges for the delivery of the service.

Multi-element tariffs are best suited to the recovery of the charges for the supply of energy. The level and value of the elements within any given charging structure must always ensure that the operation remains profitable, competitive, and retains sufficient flexibility to allow growth and development of the overall project.

The competitive element of the tariff is, perhaps, the most important element in tariff design. If the tariff is too high, sales will be severely restricted and target levels will not be achieved. With too low a tariff level, the sales volume will be achieved, but the economic return and profit levels will suffer.

To assess the competitive tariff level it is necessary to analyse the competitor costs, not only for the supply of fuel, but also for the full costs of heat production. This analysis will typically include the energy value of fuel, fuel price at the achievable energy value, boiler net seasonal efficiency, capital costs, operational and maintenance costs and costs of space. Environmental benefits associated with this type of scheme may have value, or may in future attract tax relief and/or special grants.

2.5.2 Tariff

It is generally agreed that the most effective approach on metered systems is to employ a three-part tariff, with a connection charge, a standing charge and a charge for energy consumed. Tariff elements should therefore reflect the costs of providing, distributing and selling heat; they will need to take account of the effects of inflation, operational cost charges and fuel price fluctuation.

For unmetered schemes, a two-part tariff may be adopted, with a connection charge and a standing charge that may vary from month to month, to match the cash flows associated with the higher energy consumption periods.

For projects involving a local authority, the nature and proportion of the charges need careful consideration and coordination with rent account and welfare benefit systems. Charges for many operational elements can legitimately be incorporated into the rent account, rather than appearing separately as elements of the standing charge. This provides a ‘secure’ collection regime. Some elements charged to the rent account may be eligible for payment through the welfare benefit system, thereby reducing the cost effect of providing adequate heat to families with the lowest disposable income.

2.5.3 The connection charge

To stimulate market growth and to attract a degree of ‘loyalty’ from consumers, a connection charge should be levied. The level of this connection fee is unlikely to be high enough fully to cover the costs of installing the community heating network or the heat metering equipment. The connection charge can be based upon a fixed, or preferably a sliding, scale relating to the overall connected capacity (kW) of the customer’s heating equipment. The age of existing boiler plant should be taken into account, resulting in lower rates for new boilers and full rates for customers facing boiler replacement investment in the near future.

2.5.4 The standing charge

This charge is intended to recover the initial fixed operation costs. These will vary from project to project, but would generally include:

- rates, rents and easements
- insurances
- office overheads.

The standing charge may also incorporate a major element of the financing costs for the installation of the initial community heating mains infrastructure and heat source(s), and an element of the maintenance charges.

This charge is a fixed charge, linked to the connected capacity (kW) of the customer's heating equipment or to the maximum water flow rate (m^3/s) required.

2.5.5 The energy charge

The energy charge is used to recover the variable costs and cost of sales elements, which typically include:

- fuel and lubricants
- pumping, pressurisation and water treatment
- sales-related costs
- profit.

The energy charge is recovered at a rate per kWh of delivered energy.

The simplest form of tariff would be composed of a low energy price, in line with the true fuel-related costs of the competitor fuel, and a relatively high standing charge representing the displaced costs of the provision of energy.

The reality of applying such a tariff may, particularly in the initial phases of a project, be prohibitive within the target market. There is little point in trying to sell energy with a very high standing charge and a low energy charge to a market that does not have experience of this form of cost presentation.

In such circumstances, it may be necessary to raise the energy charge and reduce the standing charge. Obviously, in these cases, great care must be taken when assessing the target market to ensure that there is sufficient volume of heat sales to cover all fixed operational costs, to provide an acceptable rate of return on capital investment and provide the required level of profit.

An incentive within the tariff may be included to encourage customers to operate heating systems so as to produce a low return temperature. This would be particularly important for steam turbine CHP schemes.

2.5.6 Indexation

Any tariff structure should incorporate appropriate indices to ensure that the services offered maintain or improve the competitive market position. Different tariff components may have different indices applied to them, depending on their cost background.

In general, prices should follow the general trends of the competitor market, while ensuring that company performance does not suffer. Indexation should follow the operational costs, the investment costs and the fuel elements for the project as closely as possible.

When evaluating the tariff structure, consideration should also be given to the expansion of the business to ensure that the cost structure and the income streams after indexation do not allow for divergence.

The Government publishes a number of bulletins and digests which provide statistical information relating to costs of employment, energy prices, retail price index (RPI), and

gross domestic product (GDP), all of which will provide accurate, reliable and independent statistics upon which the structure of the indexation formula may be based.

2.6 FORMATION OF A COMMUNITY HEATING ENTERPRISE

2.6.1 Energy services for the public sector

The Government is actively encouraging the greater use of energy services within the public sector. While contracting out any service will be a difficult process, in most cases the benefits of an energy services partnership (energy savings, finance, and risk transfer) will justify the initial effort. The increasing delegation of budgets and responsibilities to operational units, the emphasis on the application of the Private Finance Initiative (PFI) and changes in Treasury rules are making it easier to contract out. The public sector now has the same opportunity as the private sector to realise the economic and environmental benefits offered by energy services.

The activities that make up an energy services agreement will currently be undertaken by site staff, or by a number of contractors. In many cases these activities may be funded out of different budgets, and may be managed by different branches of the organisation. The key feature of the energy services approach is to maximise the benefit by integrating as many of these activities as are viable under an energy services agreement. In addition, the energy services provider can inject the innovative solutions and capital investment that are required to increase the cost savings.

2.6.2 Structure of the business vehicle

Due to the investment and infrastructure required, CH systems tend to be undertaken by two or more parties working together. The manner in which the project is run will depend both upon commercial issues, which will be for the individual parties to decide, and, for public bodies, their legal constraints. Local authorities' abilities to trade, ie to sell goods and services to third parties, are governed by the Local Authorities (Goods and Services) Act 1970. This legislation permits authorities to trade with other local authorities and to designated public bodies. The DETR is looking at ways of rationalising the way public bodies are designated so as to make it easier for authorities to set up partnership arrangements. For the longer term the Department is looking at authorities' trading powers and how they will take account both of the manifesto commitment to place on councils a new duty to promote the economic, social and environmental well-being of their area and the implementation of the best value regime.

These possible changes to the legal framework could affect arrangements between partners on CH schemes. Consequently, when authorities consider such arrangements and the way in which individual projects are to be run, they and their potential partners will wish to bear in mind local authorities' current legislative powers.

The term 'joint venture' has no specific meaning in English law. It describes a commercial arrangement between two or more economically independent entities. In practice, the legal form of a joint venture is likely to be determined by:

- the nature and size of the enterprise
- the identity and location of the participants
- the commercial and financial objective of the participants.

When setting up a CH scheme as a joint venture it is necessary to consider the relevant provisions of the law of contract, company and partnership law as well as considering the impact of tax law.

In almost all joint ventures, the basic choice to be made is whether or not a separate legal entity will be established as a vehicle for the joint venture. It is usual to distinguish

between a conventional business joint venture and a joint venture formed to carry out a single-purpose project. For the parties involved in a community heating scheme it is often necessary to form a single-purpose vehicle, as each heating system will have its own specific requirements. This will be achieved by forming a company under the Companies Act. The corporate structure typically involves vesting all of the trading activities, assets and liabilities relating to the operation of the CH scheme in a single vehicle.

The advantages of a corporate structure are such that for most business joint ventures and for many projects the limited liability company is likely to prove the most appropriate vehicle.

As a separate legal entity the joint venture company can own and deal in assets, sue and be sued and enter into contracts in its own right. The most significant advantage of establishing a company is perceived to be the ability of participants to limit their liability in respect of liabilities and losses of the joint venture business. However, unless the joint venture company is creditworthy in its own right, it is unlikely that the shareholders will be able to avoid having to support the joint venture through provision of guarantees or other assurances to third parties. At the same time, the company will have to observe the various statutory requirements designed for the preservation of its capital; for example, the rules in relation to the distribution of profits and the provision of financial assistance.

In terms of overall control, and financial and tax planning, the corporate structure provides considerable flexibility through the creation of different types of share and loan capital as well as the ability to establish the joint venture through a group of companies in which the participants can have different interests. A company can also create a floating charge over its assets, which is often a requirement of external finance.

Legal relationships between participants and between them and the company will be governed by the Memorandum and Articles of Association and a separate shareholders' or joint venture agreement which they enter into, together with related agreements.

Depending upon the pattern of shareholding and the provisions of the agreement, the company may be a 50/50 'deadlock' company or controlled' to a greater or lesser extent by a single shareholder or group of shareholders. Detailed provisions in relation to the control of the joint venture business and its management will be set out in the shareholders' agreement or the Memorandum and Articles of Association.

The shareholders' agreement and the Articles will contain detailed provisions covering situations in which shares in the joint venture company may or must be transferred. Subject to this, the corporate structure through the issue and transfer of shares can accommodate the withdrawal of participants from the joint venture, and the arrival of new ones, without necessarily affecting the business.

A company contemplating participation in a joint venture will wish to consider carefully the impact of its interest in the joint venture and existing group structure and financial arrangements, group accounts and taxation. For this purpose it may be relevant to consider whether or not the joint venture company would be a 'subsidiary' or 'subsidiary undertaking' of the company concerned. In particular, a local authority must be aware of, and comply with, the rules regarding ownership of companies and accounting procedures.

The circumstances and manner in which a joint venture can be terminated by the participants will be covered by detailed provisions in the joint venture or shareholders' agreement. The termination of the joint venture does not, of course, necessarily involve the winding-up of the joint venture company or the cessation of its business. There may simply be a change of shareholders. However, the termination may result in a winding-up under the Companies Act.

2.6.3 Private Finance Initiative (PFI)

PFIs are designed to increase the involvement of the private sector in public sector projects. Instead of providing the relevant infrastructure or service (eg CHP), the public sector simply pays the private sector to provide an asset-intensive service (eg delivery of heat). The contractual form of this type of partnership is design, build, finance and operate (DBFO). This broadly reflects the responsibilities (risks) assigned, under a single and comprehensive contract, to the service provider.

PFI projects can be financially free-standing (where the private sector undertakes the project on the basis of the cost being recovered entirely through charges for services to the final user). They can also operate through joint ventures (where the cost of the project is met partly from public funds and partly from other sources).

The PFI applies to all parts of the public sector, including government departments and local authorities. Measures have been introduced since 1995 to encourage new forms of collaboration between local authorities and the private sector — particularly in relation to the improvement of buildings and rationalisation of land holdings. PFIs can be extended to all types of projects, and local authorities are open to suggestions from the private sector as to how PFI can be applied to bring projects to fruition*.

In the first year of a PFI scheme the nature of support is likely to be by means of Special Grant; thereafter it will be by means of Revenue Support Grant. Further information may be obtained from the Local Government Capital Finance Division, on 0171 890 4241.

*Housing Revenue Account (HRA) land is, however, excluded unless it is used solely as a site for equipment employed in heating or lighting houses or other buildings.

2.6.4 The Public Private Partnerships Programme (4Ps)

Recognising the opportunities now open to local authorities for generating investment in service infrastructure, the Public Private Partnerships Programme (4Ps) has been established with the aim of delivering greater investment in local services through the PFI and other forms of partnership between the public and private sectors. It is intended that through such partnerships, enhanced services can be delivered to local communities in the most cost-effective way. The 4Ps has been set up by the Local Authority Associations in England and Wales with all-party support, and was launched on 11 April 1996. It is funded by top-slicing the Revenue Support Grant made to local authorities annually.

With an initial life of three years, the 4Ps has, among others, the following objectives:

- to lobby government for changes to the regulations that apply to local government finance where these hinder the development of PFI and other forms of partnership with the private sector
- to identify and assist in delivering existing and new council pathfinder projects — in such key areas as housing, heating, education, transport and leisure — which can be repeated by other local authorities
- to compile a database of projects and private sector companies working in public/private partnerships and to develop training programmes for local authorities on PFI procurement approaches.

In short, the 4Ps is a dedicated unit with the remit to assist local authorities in progressing PFI and other partnership schemes. The structure of the 4Ps consists of a board of nine representatives from local authority associations in England and Wales and the private sector. The board is responsible for directing the work of the eight-member executive, the latter which is drawn from both the private sector and local

government.
The 4Ps can be contacted at 35 Great Smith Street, Westminster, London SW1P 3BJ
Tel: (0171) 664 3145. Fax: (0171) 664 3178

2.6.5 Local authority position and duties

In the early days a number of local authorities obtained local act powers to enter into CHP/CH schemes. Now, however, all local authorities have the powers in section 11 of the Local Government (Miscellaneous Provisions) Act 1976. Thus, authorities can build and operate the necessary plant to produce and sell heat and electricity.

If the role of the company is given an economic development dimension, it may be possible to rely on section 33(2) of the Local Government and Housing Act 1989. However, authorities wishing to set up or obtain shares in companies should bear in mind the requirements of the 1989 Act and of the Local Authorities (Companies) Order 1995. This is not the place for detailed consideration of these requirements, however, briefly they are: that where an authority has less than a 20% involvement in a company, that company will be regarded as being in the private sector; where the authority has 20%-50% involvement then the company may be considered to be subject to public sector influence depending on the business relationship between the authority and the company; and where the authority has more than 50% involvement, the company is public sector controlled. Public sector influenced or controlled companies are regulated in a number of ways set out in the Local Authorities (Companies) Order 1995, the most significant of which is the requirement to treat certain financial transactions of the company as if they were the transactions of the authority itself. It is therefore advisable, where possible, to avoid regulation by the local authority having 20% or less interest in the company.

It is worth noting that there are a range of ways in which the Public Private Partnerships (PPPs) can work, these include joint ventures (which may or may not be companies) and local authority companies, PFI schemes and other less formal arrangements. Some joint ventures and local authority companies are involved in PFI schemes.

If it is decided that a company is an appropriate way of proceeding it may be worth considering a shareholders' agreement. This can give the minority shareholder a so called 'golden share' which requires that their consent is given on decisions taken relating to:

- priority of supply to local authority tenants
- controls over charging policies
- restrictions on material changes in the company's business
- dividend policy
- remuneration of directors.

In this way potential conflict at board level for the local authority member between acting in the best interests of the company and the authority can be alleviated. Care should be taking in drafting such agreements to ensure that they do not affect the 'business relationship' and give the authority influence over the company.

There has been some concern in the past over local authorities' power to enter into contracts, particularly for PFI deals. The Local Government (Contracts) Act 1997 which received Royal Assent in November 1997 was introduced to remove these private sector concerns. Specifically, the Act:

- confirms that local authorities have the power to enter into a wide range of contracts for the provision of assets and services where they have an established power or duty

- empowers local authorities to issue certificates for contracts establishing their

lawfulness between the parties to the contract

- enables the parties to agree compensation terms in the event that the contract is challenged by a taxpayer or the auditor and subsequently set aside (declared *ultra vires)* by the courts.

2.7 FINANCING OPTIONS

2.7.1 Scale of the project

Commercial banks, including the English and Scottish high street banks and international banks with London branches, provide long-term project finance loans which can be suitable for funding CHP projects. Project finance is normally defined as funding for the development of a project where the sole source of repayment for that funding is the earnings generated by the project once it has been completed.
It must be remembered, however, that commercial banks do not provide risk funds. They do not share in the risks and rewards inherent in a project for which they lend; rather they lend only where the risks are transferred away from the company developing the project via the commercial contracts surrounding the project. This concept is described in more detail later. The process of documenting such an arrangement is very time-consuming and expensive and is rarely suitable for projects with a capital cost of less then £10 million. Straightforward bank debt without the contractual structure could be used, but this would require the guarantee of one or more sponsors and would involve full recourse to that guarantor's balance sheet in the event that the project could not service its debt. Smaller-scale projects will normally require a high proportion of equity funding in their overall financing package and the following section deals with such potential sources.

2.7.2 Sources of finance for smaller schemes

This section of the Guide is designed to assist owners and operators of existing community heating schemes, and potential new schemes, in identifying appropriate funding sources that are currently available. In recent years local authorities have tended to bid for a variety of funds, and it is likely that future projects will often be funded from a basket of measures, and these include funding for privately operated schemes.
The main restrictions on sources of finance will depend on two matters:

- the ownership of the premises supplied
- the nature of the commercial agreement between the occupier, the landlord and the scheme operator.

If the premises supplied by a community heating scheme are owned by a local authority and are provided as social housing under Part II of the Housing Act 1985, any commercial arrangement between the scheme provider and the local authority must be regulated by the requirements of the Housing Revenue Account (HRA). If the scheme provider is the local authority, any revenue spending (such as capital charges) relating to the investment must be accounted for within the HRA. If the scheme provider is a private sector controlled (and financed) organisation, any commercial arrangements with the local authority must comply with the requirements of the regulations governing local authority capital finance. In particular, these regulations place restrictions on commercial arrangements that are deemed to be 'credit arrangements'. They also provide specific guidance on arrangements that are procured under the PFI.
In the event that the scheme supplies HRA property pursuant only to a direct

arrangement between the tenant and a private sector controlled (and funded) scheme provider, the local authority is not restricted by the HRA funding and accounting requirements, or the capital finance regulations.

Schemes may also proceed by the equipment supplier finance route. Plant which is outside the dwellings can be financed and operated by private contractors; this includes boiler houses, CHP units, and main heat distribution networks. This can be achieved by selling or leasing appropriate plots of land and selling the energy at the boundary.

Housing associations and other registered social landlords, are not affected by the same capital finance restrictions as local authorities. This includes dwellings transferred under Large Scale Voluntary Transfer from local authorities. However, they will be anxious to ensure that rent levels are kept to affordable levels. Private householders and businesses are free to enter into any suitable financial arrangement.

Small-scale schemes involving local authority housing may be financed by credit approvals issued by Central Government. These comprise:

- Basic Credit Approvals (which include a housing element determined through the Housing Investment Programme (HIP) process)
- Supplementary Credit Approvals (SCAs)
- Usable Capital Receipts to fund housing investment.

The Government has issued SCAs under the Capital Receipts Initiative to enable authorities to use their set-aside receipts from the sale of council housing for investment in housing. As these resources are limited, use of private finance where possible can release credit approvals for other projects.

In most instances, operators of private sector controlled (and funded) schemes will have commercial arrangements with both tenants and landlords. The funding for connection of privately owned dwellings will normally fall to the householder, possibly using mortgage arrangements. In the future, private developers can be expected to consider CH with CHP alongside other heating options.

Regeneration projects often combine social housing and private sector housing in partnership projects combining funding from the private sector and central government. Public sector funding is available through the:

- Single Regeneration Budget
- European Union Structural fund.

There are also energy-related grants available for CHP/CH and insulation measures from central government. These may include:

- HEES (Home Energy Efficiency Scheme)
- occasional grants made available via the Energy Saving Trust
- occasional grants from sponsors, eg part contribution to feasibility studies
- occasional grants from utilities, eg Standards of Performance.

Other sources of funding may be available, under certain circumstances, via lottery funding, English Heritage (eg for listed estates), and Entrust (for projects making use of landfill tax credits).

For innovative projects, it may be possible to secure funding administered by the European Union, by way of THERMIE (innovative energy efficiency techniques — demonstration programme), SAVE (supporting measures such as publications, training),

and JOULE (research and development funding).

Sources of advice

Department of the Environment, Transport and the Regions (DETR)	0171 890 3000
Combined Heat and Power Association (CHPA)	0171 828 4077
Energy Saving Trust	0171 222 0101
Design Advice Service	01923 664258
Entrust (for access to Landfill Tax Credits)	0181 950 2152
BRECSU OPET — for European funding programmes	01923 664754

Further information on finance sources relevant to housing is included in the following which are available from BRECSU: Good Practice Guide 82 (GPG 82) ‘Energy efficiency in housing’; and General Information Report 50 (GIR 50) ‘Unlocking the potential — financing energy efficiency in private housing’ and General Information Report 51 (GIR 51) ‘Taking stock — private financing of energy efficiency in social housing’.

2.7.3 Large-scale schemes

Project finance might be appropriate for CHP schemes with a capital cost in excess of £10 million. It is most frequently used where several sponsors are involved and each wishes to see the project go forward but no one is prepared to shoulder the total risk alone. The process is as follows.

- A group of sponsors come together to investigate the viability of a project. The group can include equipment suppliers, civil engineering contractors, plant operators, fuel suppliers, electricity off-takers, and heat or steam off-takers. If a simple economic analysis demonstrates that the project will have an investment rate of return in excess of a hurdle rate (for instance more than five percentage points over the yield of a 20-year government security), the group moves to the next stage by incorporating a special purpose company (SPC) to further define the economics, raise finance and implement the project. It is probable that legal, financial and engineering advisers will be appointed at this stage.

- The SPC will be owned by the sponsoring companies that will have invested seed-corn equity. The SPC will need independent management to negotiate the following commercial contracts:

  — a construction contract on a fixed-price turnkey basis that will give certainty that a working plant will be delivered by a stated date
  — an operating contract for a committed long-term cost
  — a fuel supply contract with a unit price and an escalation factor which ties in with the electricity and heat off-take contracts
  — an electricity off-take contract as above (or several)
  — a heat off-take contract as above (or several)
  — a full package of insurance cover.

The project’s net cash flow is contractually underwritten because the above contracts are long term and price certain. Banks will lend against that cash flow. If the cash flows justify it, banks will lend up to 90% of a project’s capital costs, including interest payments accrued during the construction phase. Loan repayments will be phased over the period six months after project completion up to the last years of the SPC’s

commercial contracts. This recognises both the long-term nature of the project's economic life and the essential security given by the existence of the commercial contracts.

2.7.4 Efficient sources of funds

- ***Commercial banks***. These are the most common source of finance.
- ***Leasing companies***. These are particularly relevant if the sponsoring companies cannot use the project's capital allowances via consortium relief. It is very unusual for leasing companies to take project risk and it is normal to have a bank guarantee facility running in parallel, but this can still be cost effective.
- ***Venture capital***. The risk return profile of infrastructure projects such as CHP/CH is unlikely to fit with the requirement of venture capital, although as suppliers of quasi-equity this source can make a useful contribution by reducing the need for sponsor equity.
- ***Pension funds and insurance companies***. There are examples of institutions buying bonds issued by project companies. This is unlikely to occur before project completion and it is most relevant in refinancing expensive bank debt which funded the construction phase.

2.8 RATING

For many years the rateable values of utilities have been prescribed by the Secretary of State in order to overcome technical problems which arise from assessment using conventional methods. The conventional method of assessment is to calculate an amount equal to a rent at which it is estimated the hereditament (the unit of property that is liable for assessment to non-domestic rating) might reasonably be expected to be let from year to year on a full repairing and insuring lease.

Under prescribed assessment, the electricity supply industry is rated according to formulae contained in regulations made under paragraph 3 of Schedule 6 to the Local Government Finance Act 1988. The rateable values of hereditaments occupied by major electricity generating and transmission undertakers, such as National Power plc and the National Grid Company plc, are entered in the central rating list. Rates due under the central rating list are payable direct to the Secretary of State.

Hereditaments occupied for the purposes of CHP and CH systems have their assessments entered in local rating lists. Provided the following conditions are met:

(a) The hereditament comprises load, plant or building used or available for use for the purposes of generating electricity, where:

  (i) such use is its sole or primary function; or
  (ii) its primary function is in connection with a scheme for the production for sale of both electrical power and heat; or
  (iii) its primary source of energy is the burning of refuse.

(b) The generating plant:

  (i) uses wind, tidal or water power as its primary source of energy; or
  (ii) its primary source of energy is the burning of refuse, and neither paragraph (i) or (ii) of (a) above applies, has a declared net capacity of 25 megawatts or more; or
  (iii) has a declared net capacity of 500 kW or more.

(c) The hereditament does not fall to be shown in a central rating list.
the rateable value of the hereditament is also calculated by formulae as follows:

- £5810 rateable value per megawatt of net declared capacity for wind or tidal power; or

- £11 620 rateable value per megawatt of net declared capacity in all other cases.

Rates for hereditaments in the local rating lists are collected by the local authority for the area in which the hereditaments are located.
A CHP/CH system that does not meet the prescribed conditions will be rated in accordance with conventional methods of assessment for nondomestic property.
It seems likely that all power generators will be returned to conventional assessment with effect from the 1 April 2000.

ENGINEERING DESIGN 3

Part A — System design

3.1 SYSTEM CONFIGURATION

3.1.1 Introduction

This section of the Guide provides information on the design and engineering of CH. Many other engineering details will need to be considered but advice on these is available from other standard publications. This Guide concentrates on those aspects of CHP and CH which are different to engineer than conventional heat and power solutions. The differences can be summarised as follows:

- The total efficiency of CHP/CH is much higher (about 85%) compared with separate heat and power production (about 55%), with commensurate environmental benefits (figure 1).

- CHP/CH supplies existing properties that may or may not already have heating systems suitable for connection to a CH network. The selection of appropriate consumer connections is therefore important, influencing the choice of control at the consumer’s interface with the scheme.

- CHP/CH is often developed progressively. System growth will be assisted by a design and control philosophy that permits a flexible development strategy.

- CHP/CH is on a larger scale than heating systems for single buildings; potentially it can be city-wide. Close attention must therefore be paid to the design of CH, to the selection of appropriate design pressures, and to the control of pressure during operation so that an economic scheme results.

- The production cost of CHP heat and the type of CHP plant generally depends upon the temperatures at which the heat is produced. The selection and control of temperatures for heat production, distribution and use is therefore of particular significance for the total economy of CHP/CH.

- The operating cost of CHP heat is very low, but the capital costs of CHP/CH are relatively high and are related to the peak heat demands. It is therefore not good

practice to seek to reduce overall heat consumption if in so doing an increase in the heat supply capacity is required to meet peak loads. The general emphasis of CHP/CH control should be on reliability, continuity and modulation, rather than on intermittence and associated high peak demands.

- Typically, the heat output from a CHP plant will cover up to 50% of the peak load with the remaining 50% covered by lower capital cost peak boilers. With this arrangement, 80%-90% of the annual heat consumption is supplied from the CHP plant. The different balance between fuel and capital costs for CHP/CH, compared with heat-only boilers, also has particular implications for the cost-effectiveness of heat metering.
- District cooling based on absorption chillers can be implemented to improve the overall viability of the scheme by increasing the utilisation of CHP heat during summer months.

The physical parameters of a CHP/CH system are determined by the following factors:

- characteristics of heat load; temperatures and pressures at which the heat is required
- size, location, density and type of building development in the area to be supplied
- characteristics of future development
- design of existing consumer installations
- characteristics and type of CHP heat source plant to be utilised
- type and location of peak and reserve boilers
- type of heating mains distribution suitable for use in the heat load area
- business development plans of the heat supplier.

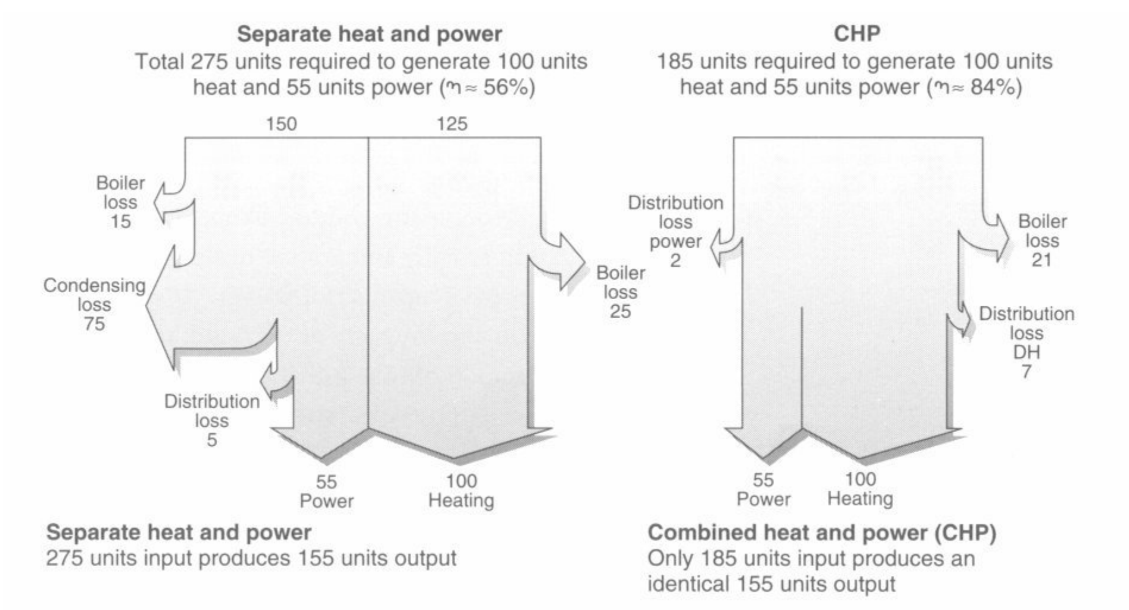


Figure 1 CHP is much more efficient than separate heat and power

The major elements of CHP/CH system design should be considered throughout the design process in the light of the above factors, starting from optimisation of heat and power production, distribution system and consumer connections, including feasibility and viability analysis.

3.1.2 Project brief

The design of any CHP/CH system should be based upon a project brief which collects together all the assumptions and parameters used to assess the feasibility and viability of the project (see section 1). The design must achieve the heat load build-up within the cost plan.

At the completion of the design stage of each part of the system a check for compliance with the assumptions and standards of the feasibility study should be made. If required, the viability analysis should be updated accordingly.

3.1.3 Heat load assessment

Although predictions of heat demand will have been made at the feasibility stage these should be the subject of a detailed review. Where uncertainties remain, some monitoring of demand profiles will be worthwhile, particularly to discover 24-hour variations in demand.

In heat load assessment, heating, ventilation and domestic hot water (DHW) should be taken into consideration to produce a load duration curve. In principle this will depend on:

- type and behaviour of the consumer (eg residential, public, industrial)
- minimum outside temperature and other climatic conditions, particularly relative humidity
- type of heating, ventilation and DHW control in the building
- usage by occupant, comfort temperature and duration of daily and annual heating
- number of occupants (for DHW)
- direction and intensity of the wind, intensity and duration of solar radiation
- location (town centre, suburban, open flat country)
- exposure or shelter due to immediate local topography
- quality of building construction, thermal capacity of envelope and leakage
- heat storage facilities incorporated in the building heating and domestic hot water systems.

Although each of these factors is important, in practice it is unlikely that they will be individually established in detail; a more overall approach is likely.

When designing for buildings that are yet to be built, use can be made of computer simulation models provided there is sufficient knowledge about the construction and use patterns.

When connecting existing buildings to the CHP/CH system, the operation records and fuel consumption data of existing heating systems provide a valuable and relatively reliable data source for heat load assessment, both regarding annual heat energy

consumption and peak demand. It should be noted, however, that in individual heating the reserve boiler capacity needs to be maintained in each building separately, whereas in a CH system the reserve capacity is also centralised and common for the whole scheme. Accordingly, the heat demand must not be derived from the total existing boiler capacity, but rather from the actual operation records of the boilers.

It is possible to take account of demand diversity in designing the heat mains and the central plant. The diversity factor is defined as the peak demand at the central heat supply source divided by the sum of the individual heat demands. A diversity factor of 0.8 to 0.95 can be applied to the space heating demand, with the lower figure appropriate for larger schemes where there is a wide mix of building types and uses, and the higher figure for smaller schemes where the buildings are more homogeneous.

When assessing the peak supply requirement and the annual heat energy at the heat generating plant (compared with consumer demand and annual consumption), network losses need to be taken into account. Here, the annual transmission and distribution energy losses need to be distinguished from the capacity losses during peak supply. The former are typically in the range of 6% to 10% and the latter from 2% to 5% in modern CH systems, depending on operation temperature, on type and condition of piping and on heat load density in the system.

3.1.4 Selection of fuels

The full spectrum of fuels will have been considered, on a long-term basis, in the feasibility study and the fuel most beneficial to the specific project will have been selected. In larger schemes, different consideration needs to be given to base load fuel and to the peak and reserve fuels. The base load capacity requires low-cost fuel (or energy source), tolerating higher investment costs if necessary. The cost of fuel for peak and reserve capacity is not so crucial; the main emphasis being on low capital and other fixed costs.

Technical, economic and environmental aspects need to be considered on a long-term basis during selection. In addition to fuel prices, the economic analysis should take into account investment costs and other operational costs. Furthermore, different fuels provide different CHP process alternatives, and consequently plant efficiencies and outputs vary, eg in regard to power-to-heat ratio and part-load efficiency. An example is a gas-fired combined cycle, compared with coal-fired steam turbine plant.

Domestic refuse incineration may be a low-cost fuel option for the build up of a CHP/CH project, depending upon local refuse disposal policy. Similarly, local industrial process waste heat sources should be investigated as a possible energy source for the project.

Regarding environmental aspects, modern process and emission abatement technology can satisfy practically all requirements set by authorities, regardless of the fuel in question, (with different cost implications). Since CHP/CH plant requires a central location in the vicinity of the heat load, the site selection and necessary approvals are of the utmost importance. Typically, at least for a new site, a comprehensive environmental impact assessment (EIA) is required covering aspects such as emissions into air and water, hazards regarding soil, required transport, noise and vibration, biological impacts, possibly even social impacts. This may also have an effect on fuel selection, depending on the site (see appendix 2).

The project should be designed to accept likely available alternative fuels, and to give flexibility and security in operation, providing costs are not increased significantly. Whereas the study will have been based on the prediction of fuel costs over the life of the plant, the design should enable alternative fuels to be used according to price and availability.

3.2 OPTIMISATION OF SYSTEM TEMPERATURES

3.2.1 General

The selection of the temperature parameters of the system has major implications for the overall economics of CHP/CH, influencing the choice of equipment and operating costs over the lifetime of the scheme. The fundamental design parameters to be selected for any CHP/CH scheme are:

- flow and return temperatures supplied to the buildings at design conditions and at part-load; if a building uses a variable flow temperature weather-compensated system for part of the space heating, the required temperatures must be satisfied, as must temperatures for constant temperature circuits for domestic hot water, fan convector and heater batteries
- flow temperature at design conditions (eg -3°C external air temperature) produced at the CHP heat generating plant
- flow temperature at design load conditions at the furthest consumer
- temperature control by consumers (although only two-port control valves should be used for CH)
- minimum acceptable flow temperature at minimum flow condition.

During the design phase it is important to review the heating systems and temperature controls of the buildings to be connected to the CHP/CH system. There may be constant temperature circuits with bypass controls, which are not efficient for the cooling of the CH circulation water. It is very important to maximise the cooling (to minimise the return temperature) of the CH water in each building. Low return temperature is important for the overall economics of the system, affecting transmission capacity utilisation, pumping costs and CHP power production.

3.2.2 Temperature constraints

Heat mains

Pre-insulated piping systems are manufactured according to European Standards EN 253, EN 448, EN 488 and EN 489. This piping system consists of steel carrier pipe, polyurethane insulation and high-density polyethylene casing. it is typically designed for 16 bar and up to 120°C continuous operation temperature. The temperature can be even higher temporarily (up to 140°C).
Alternative pre-insulated pipe systems are also available where the carrier pipe is plastic. These are more flexible, leading to fewer site joints; smaller diameters can be delivered in coils of 50 m length. Unlike steel, they are not susceptible to corrosion from ground water or community heating water. The long-term strength of the material is, however, very different to steel and the maximum pressure depends on temperature. A 20-year life can be assumed only for temperatures less than 90°C and pressures less than 6 bar. Such a system may offer cost advantages when used for low-temperature schemes.
Building heating systems

CH can supply heat to radiator-based central heating or warm-air systems. In large conurbations many dwellings already have gas-fired radiator central heating and

consideration should be given to the connection of existing systems to CH, since any savings on the internals will have an appreciable effect on the economics.
An acceptable maximum flow temperature entering a dwelling is 90°C. A flow temperature lower than 90°C is considered to give safe surface metal temperatures within a normal domestic environment according to previous BSRIA research (Billington, 1976). For elderly or disabled occupants low-surface-temperature radiators should be used with a maximum surface temperature of 43°C (Department of Health Ref DoH and B54086, 1983). Pipe covers may also be necessary over surface-run pipework.
Traditionally, internal heating systems in the UK are designed for 82°C/71°C (flow and return). This is to minimise the size of radiators and has been suitable for heating systems supplied by individual boilers. The resulting mean temperature of 76°C for the heat emitters is a major constraint on CH system design for existing heating systems.
Converting a system to operate at 90°C/60°C is feasible, provided the rebalancing of the secondary side systems can be achieved. Building fabric is often improved in tandem with the introduction of CH, in which case the resultant oversizing of radiators allows the mean temperature to be reduced, lowering the return temperature without sacrificing comfort. For example, a mean temperature of 65°C based on 80°C/50°C could be used if heat losses from the building can be reduced by 25%.
The supply temperature should not be reduced below the level required to provide an adequate recovery time for storage-water heating and to ensure that stored water can be maintained above 60°C for legionella control. This effectively sets a lower limit of 70°C for the flow temperature.

3.2.3 Network temperatures and optimisation

Selecting low temperatures for distribution will improve the efficiency of electricity generation and reduce mains losses. However, if as a result the temperature drop through the CH network is reduced, then the volume of water required is greater and mains and pumping costs are increased. An optimisation process is therefore necessary for each scheme.
For the distribution system two design temperature levels are commonly used.
Type I.

Medium temperature is up to 120°C and 16 bar for larger CHP/CH systems with high static pressure, usually with indirect consumer connection.
The cost of the community heating network for large-scale CHP/CH tends to dominate the overall optimisation. Ensuring that the differential between peak design flow and return temperatures is as large as practicable, usually at least 50°C, reduces both capital and running costs.
The balance between electricity production by the CHP plant and electricity consumption by the pumps varies with scheme load distribution. The variable flow and variable temperature is generally used in CHP/CH to minimise the heat losses and maximising the net electricity production. It is common practice in large city-wide CHP/CH systems to use a peak design temperature of 120°C but to vary the supply temperature in accordance with ambient air temperature, using as low a supply temperature as possible to satisfy consumer requirements. Some adjustment can be made based on wind and rain. The flow temperature can be varied with outside temperature down to a minimum flow temperature of about 70°. This is particularly suited to steam turbine systems supplying buildings that are heated continuously.
This method gives good flexibility for future expansion, because initially the 16 bar limit is unlikely to be reached.

Type II.

Low temperature and low pressure (90°C and 6 bar) for smaller-scale CH systems with small topographic variations suitable for direct consumer connection, IC engine CHP and all-plastic pipe systems.

For smaller CHP/CH systems utilising IC engines the low temperature system with a maximum supply temperature of 90°C is preferable and would make it possible to use all-plastic pipe distribution systems. If there are plans for future expansion of the scheme, all-plastic pipes and low temperatures are not suitable because they will limit the pressure to 6 bar and the temperature to 90°C maximum, unless local heat transfer stations are used.

If the pressures and temperatures are suitable, the ‘direct connection’ is the lowest-cost method of connection (see section 3.8). This will increase the distribution mains cost, because of the smaller temperature difference, so direct systems are advantageous mainly for small and local CH systems. The CH water passes through the dwelling heating circuit; no hydraulic separation is made between the utility system and the consumer’s system. In order to facilitate the maximum practical use of direct connections the community heating system must satisfy the constraints imposed by the most common dwelling central heating systems, ie a flow temperature of 90°C (see section 3.3.3).

For the CH company the indirect connection of consumers is preferable, because the distribution system and house internals would be hydraulically separated, so that the possible make-up water consumption in a house internal system would be the responsibility of the customer. Hydraulic separation is more flexible for operating temperature and pressure, and is safer in the event of damage to the house internal heating system, or pressure transients in the CH system.

In Western Europe variable temperature systems are currently most common, with heat exchangers to reduce the temperature to consumer systems, but some projects in Denmark and Germany have adopted constant low temperature distribution, particularly when connecting small housing areas to CH.

Lower standard design temperatures for new heating systems in the UK would help to make heating systems more suitable for CH. In Scandinavian countries the design temperatures for new houses are 60°C/40°C, but for UK conditions the direct step to 60°C/40°C is too large and so 80°C/50°C or 70°C/40°C is recommended for new buildings. This would slightly increase the radiator size, but the risers and house internal piping sizes would be reduced and also the amount of water to be circulated would be reduced. Lower primary return temperatures can also be specified for the heating of DHW; the instantaneous plate heat exchangers can be sized to produce return temperatures as low as 25°C for a relatively small cost penalty.

3.2.4 Summary of optimisation of system temperatures

The selection of the CH system’s operating temperatures involves a complex optimisation of the fixed and variable costs involved in producing, distributing and utilising both the heat and electricity. Computer models for the plant (turbine and CHP) and CH networks should be utilised for simulation and optimisation of a proposed CHP/CH system. It is not possible to provide definite rules; site-specific variations determine the optimum solution. The following general conclusions can, however, be stated.

- If the scheme consists predominantly of individual housing then the direct connection of each dwelling to the network will be the lowest-cost solution, but

the flow temperature will then be limited to 90^{o}C (provided the pressure constraints can be met (see section 3.4).

- If existing radiator heating is to be retained on the scheme, then for a flow temperature of 90^{o}C the lowest return temperature would be 60^{o}C. However, the size of existing radiators should be reviewed against the building heat demand, particularly where fabric improvements have been made, to see if lower mean radiator temperatures would provide sufficient heat output.

- If new radiators and hot water systems are being specified, temperatures of 80^{o}C/50^{o}C or lower should be used, which would be compatible with the connection of the buildings to a larger-scale system at a later date.

- Where the buildings are predominantly non-residential or large residential blocks, the cost of indirect connection is less significant. For large schemes higher flow temperatures up to 120^{o}C are likely to be more economic.

- If steam turbine CHP plant is supplying the scheme then reducing the flow temperature in relation to outside air temperature will be economic (section 3.6).

3.3 OPTIMISATION OF SYSTEM PRESSURES

3.3.1 General

Having determined the heat demand and temperature parameters of a system, the pressure field of a heat distribution network is the principal design problem to be solved. The optimisation must take account of the limits to materials and equipment installed, and seek to minimise the overall lifetime costs of the CH system.
There are two main requirements for the design.

- Selection and design of a pressurisation system to guarantee the required minimum static pressure in the whole system to prevent cavitation and pressure transients. The minimum pressure for 120^{o}C is 2 bar a.

- Selection and design of circulation pumping. The circulating pumps overcome the friction loss of the principal distribution circuit under full-load conditions and maintain the minimum pressure difference for each consumer. Variable flow with variable speed pumping is the most economical CH distribution.

3.3.2 Maximum pressure constraints

Heat mains

Pre-insulated piping systems are manufactured according to EN 253, EN 448, EN 488 and EN 489. They are designed for 16 bar and up to 120^{o}C continuous operation temperature. With the steel carrier pipe system, the cost of the network will not be significantly reduced if lower (10 bar or 6 bar) design pressures are selected. Alternative pre-insulated pipe systems are also available where the carrier pipe is plastic. These have the advantage of being more flexible, which results in fewer site joints, because smaller diameters can be delivered in coils of 50 m length. They are also not susceptible to corrosion from ground water or CH water, as is the case with steel. The long-term strength of the material is very different to steel, however, and the

maximum pressure depends on temperature. A 20-year life can be assumed only for temperatures less than 90°C and pressures less than 6 bar. Such a system may offer cost advantages when used for low-temperature schemes.

Heating systems within buildings

The modern steel panel radiators used for CH have working pressures up to 6 bar, and in some cases up to 10 bar. Older radiators would have been tested for a working pressure of 4.4 bar. These pressures may be adequate for small residential and commercial schemes, but for larger and expanding schemes maximum pressures of 6 bar will result in too severe a constraint on the development. Either new radiators will need to be installed, or hydraulic separation of the CH network and the building heating system by means of heat exchangers (indirect connection) will be required. This is particularly so where there is significant topological variation and/or high buildings.

3.3.3 Optimisation

The introduction of a heat exchanger frees the pressure and temperature constraints on the network so that the optimum design conditions can be selected for both the CHP heat production and the network, but there are cost implications:

- capital cost of the heat exchanger, secondary pumps, secondary water supply system and controls, and associated space requirements
- operating costs of the secondary pump if secondary pumping is not already required for return mixing
- separately treated water supply for the secondary side of the heat exchangers.

These costs need to be compared with the alternatives:

- replacing the existing radiators with radiators designed for higher pressure; valves and pipework joints may also need to be replaced
- designing the network within the pressure constraints by using larger diameter mains, distributed pumping stations, pressure controls and safety relief valves.

It is preferable to design the CH system so that disruption to the existing building heating systems is minimised.

For commercial buildings or groups of dwellings (particularly high-rise flats) heat exchangers offer advantages and provide greater freedom to the designer of the network and CHP production. Modern prefabricated plate heat exchanger units are compact and achieve close approach temperatures.

Detailed consideration of variants of consumer connection is given in section 3.8.

In addition to the upper pressure limit imposed by heating systems, a lower pressure limit is imposed by the need to avoid cavitation at control valves, pumps and other high-resistance elements, and saturation of the water in any part of the CH system. The low pressure constraint will be most severe for systems having a significant variation in static pressure.

3.3.4 Summary of optimisation of system pressures

Designs should be compared using a range of pressures and with heat exchangers in various locations. Although there will be variations from scheme to scheme, there are some general guidelines.

- Schemes with significant topographical variation, high-rise buildings or long transmission mains are likely to require indirect connections to buildings with

heat exchangers.

- The indirect connection of individual dwellings will have a significant effect on capital costs — supplying a group of dwellings from a local heat exchanger substation would be more economical.
- For indirect connection a maximum pressure of 16 bar is generally an economic upper limit.
- Alternative methods of creating circulating pressures using booster pumps within the network should be examined so as to reduce maximum pressures. The system pressure distribution should give the maximum flexibility for connection of existing and new loads.
- The pressurisation and expansion system should be of the closed type to maintain good water quality and to minimise the amount of chemical dosing.

3.4 DESIGNING FOR FLEXIBLE DEVELOPMENT

The development of large-scale CHP/CH is most likely to proceed in stages, with isolated networks initially running off heat-only boilers, eventually being connected to large CHP plant. The incorporation of additional heat load to an existing network requires careful hydraulic design, and may involve the resiting of pumping stations to maintain pressures. A design in which local networks are driven only by the pressure differential across the arterial mains may impose impractical rigid constraints on the development programme.

Centralised pumping, with pumps at each production plant, and possibly booster pumping along the transmission main line, is generally the most economical pumping strategy. It may be that the booster pump station is not required in the initial phase, but its provision will increase transmission capacity and avoids having to use unnecessarily large pipes in the first phase.

3.5 SUMMARY OF CHP/CH OVERALL SYSTEM DESIGN

The most cost-effective heat distribution method for larger-scale CHP/CH systems is medium-temperature hot water (up to 120°C supply) designed for a large temperature drop. The underground pre-insulated steel pipes will be designed for 16 bar and 120°C according to EN 253. Larger buildings should be connected indirectly to the CH network; while for housing, a heat exchanger substation supplying a number of dwellings either in apartment blocks or in terraces will be more economic.

For smaller-scale CHP/CH systems low-temperature hot water (up to 90°C flow temperature) and low pressure systems (up to 10 bar g if new radiators) will be suitable. Either steel-in-plastic or all-plastic pre-insulated pipe systems may be used. Direct connection methods may be preferable, particularly for individual dwellings. Smaller CH residential developments will need to be designed to be compatible with connection at a later date to a larger CH network. The key to compatibility is to select lower average radiator temperatures than those typically used in the UK — a new standard of 80°C/50°C is recommended.

The most economical pumping arrangement will be achieved by centralised pumping with circulation pumps in each production site and possibly booster pumps along the network. In this way the development can be phased in a flexible manner. Optimisation

of power generation, CHP, distribution system, pumping and consumer connections will normally require detailed computer analysis.
Generally, with steam turbine CHP it is more economical to use operating temperatures that are the lowest possible to just satisfy the consumers requirements. Reduced heat losses, and gains in electrical production, more than offset the additional cost of higher pumping energy.

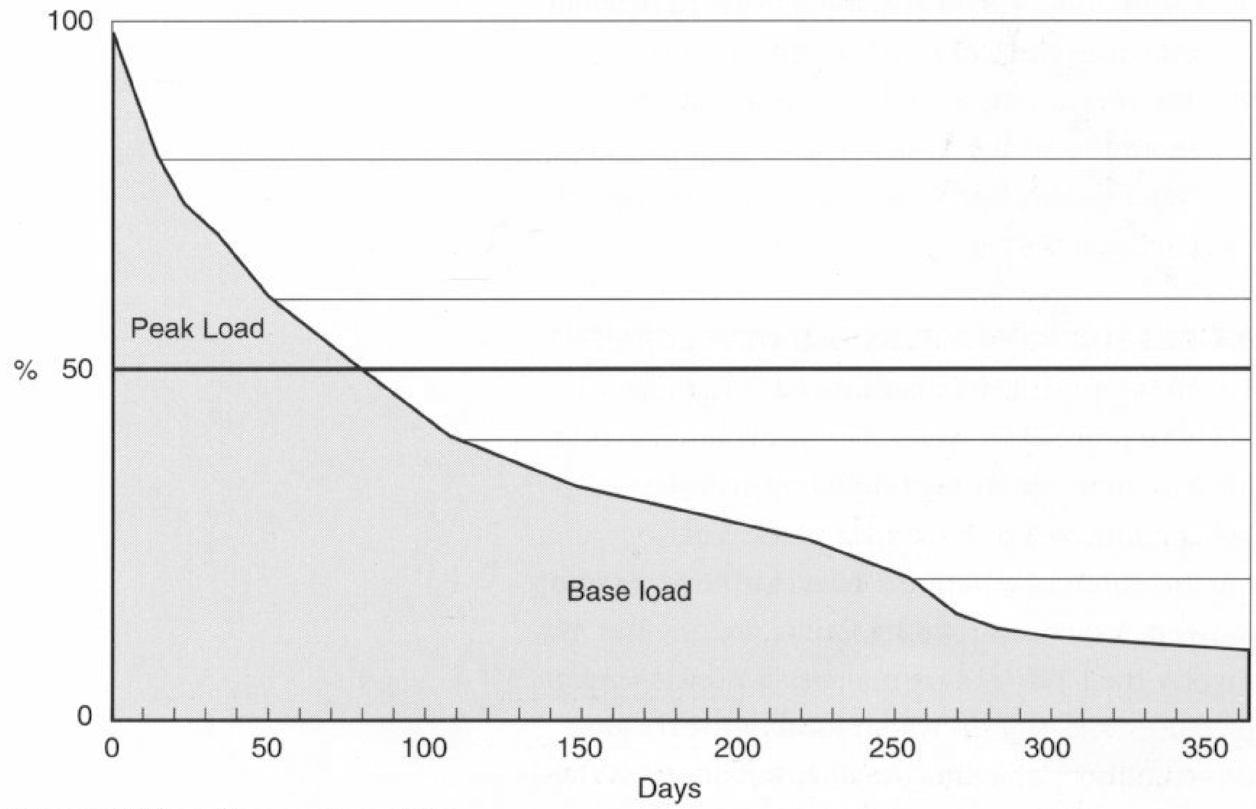


Figure 2 Duration curve of the annual heat consumption base on hourly heat demand

Figure 2 Duration curve of the annual heat consumption base on hourly heat demand

Part B — Component design

3.6 CHP AND PEAK BOILER PLANT

3.6.1 Strategic considerations

The annual heat demand profile plotted as a heat demand/hours duration curve (see figure 2) is of a peaky form. The peak heat demand occurs for relatively few hours during the year. Heat generating sources should therefore be designed so that the peak demand is met by low capital cost boiler plant. In the case of projects utilising reject or waste heat other than that associated with electricity generation, the heat should be primarily used to satisfy base load. The exact division between base and peak load

depends on the marginal number of boilers. However, this situation may vary from region to region, and will depend on the degree of security designed in. The duration curve is peaky, so 50% of the peak load typically results in about 85% of the annual heat load.

The large CHP/CH developments in Europe have been built up by the amalgamation of smaller schemes, often developed initially with boiler plant which may be relocated to new areas at a later date. A similar approach is likely in the UK; identification of existing large commercial or institutional buildings and residential group heating schemes will assist the development of a core heat market, provided the building's owners can enter into long-term commitments for the purchase of heat.

During the build-up period base load heat will have to be supplied from the lowest-cost sources, which could be waste heat from domestic refuse incineration or specific local industrial processes, simple boiler plant and/or small CHP plant, such as gas-engine-driven generators, gas turbines or back-pressure steam turbines. Subsequently, more efficient higher-cost plant will be justified as the load builds up. Extraction-condensing steam turbines, combined-cycle plant, fluidised bed combustion, and coal gasification plant may be considered.

It is easy to assume that heat from CHP plant is inexpensive, because heat from conventional power plant is wasted. However, smaller-scale power plant is generally more expensive to build and maintain. Consequently, the viability of CHP/CH projects depends on obtaining the best income from the electricity produced and ensuring that the advantages of a location nearer to the demand point are recognised in the commercial agreements. There needs to be a well-planned strategy to permit some expansion in the future but avoiding excess capital expenditure for a low return.

The range of CHP plant options covers:

- steam turbine (extraction-condensing or back-pressure)
- gas turbine/waste heat boiler combination
- internal combustion engine driven generator with waste heat recovery (spark-ignition or compression-ignition)
- gas turbine/steam turbine combined cycle.

For any specific project, the choice of the type and capacity of the initial base load CHP plant will be influenced by:

- local refuse disposal policy
- local process waste heat sources
- availability and price of alternative fuels
- adequate electricity revenue under a power sales agreement
- standby electricity generating requirement
- potential for thermal storage
- type and location of peak/standby boilers.

The optimisation of the type and capacity of the CHP plant is a complex task — typically there are several technical options, and numerous variants. The optimisation needs to cover not only the CHP plant but also the required peak boiler capacity and the possible

effects on the CH network. Furthermore, electricity sales and possible peak and standby arrangements also need to be considered. The issues dominating economic optimisation and selection are:

- capital cost of CHP plant, peak boilers, and CH network
- maximisation of electricity production and revenue
- fuel and other operating costs of CHP plant and peak boilers.

The optimisation process includes two iterative phases.

- *Technical design and optimisation of the power plant process*. Available technical options are simulated and developed, taking into account the heat capacity requirements, CH temperature parameters and sales prospects for electricity. The results of this phase will show the available power and heat generating capacity and their interdependence, as well as fuel efficiency data, for different load conditions, including part-load conditions and different CH water supply and return temperatures. The results will be used in the next phase. Initially, several CHP plant options are used in the comparison.
- *Simulation and economic optimisation of the annual operation of the power and heat generating capacity.* Here the hourly variation of the annual heat demand is optimised taking into account available capacity, fuel prices, and with the overriding objective to maximise electricity generation and revenues. Based on the results and findings, the CHP plant process and capacity may need to be recalculated.

Because of the complexity of the plant optimisation, specially developed computer simulation software is normally used for turbine and CHP simulation and optimisation. Selection will also depend upon the tariff structure for the sale of electricity and the relative value placed on capacity and units. The viability study will have selected the generic type CHP plant appropriate to the first CHP phase of the project. Some aspects of the various types of plant will be significant to the optimisation of the initial scheme and ensuring flexibility for future expansion.
The choice and optimisation of CHP plant governs the possible heating mains supply and return temperatures (see section 3.3).

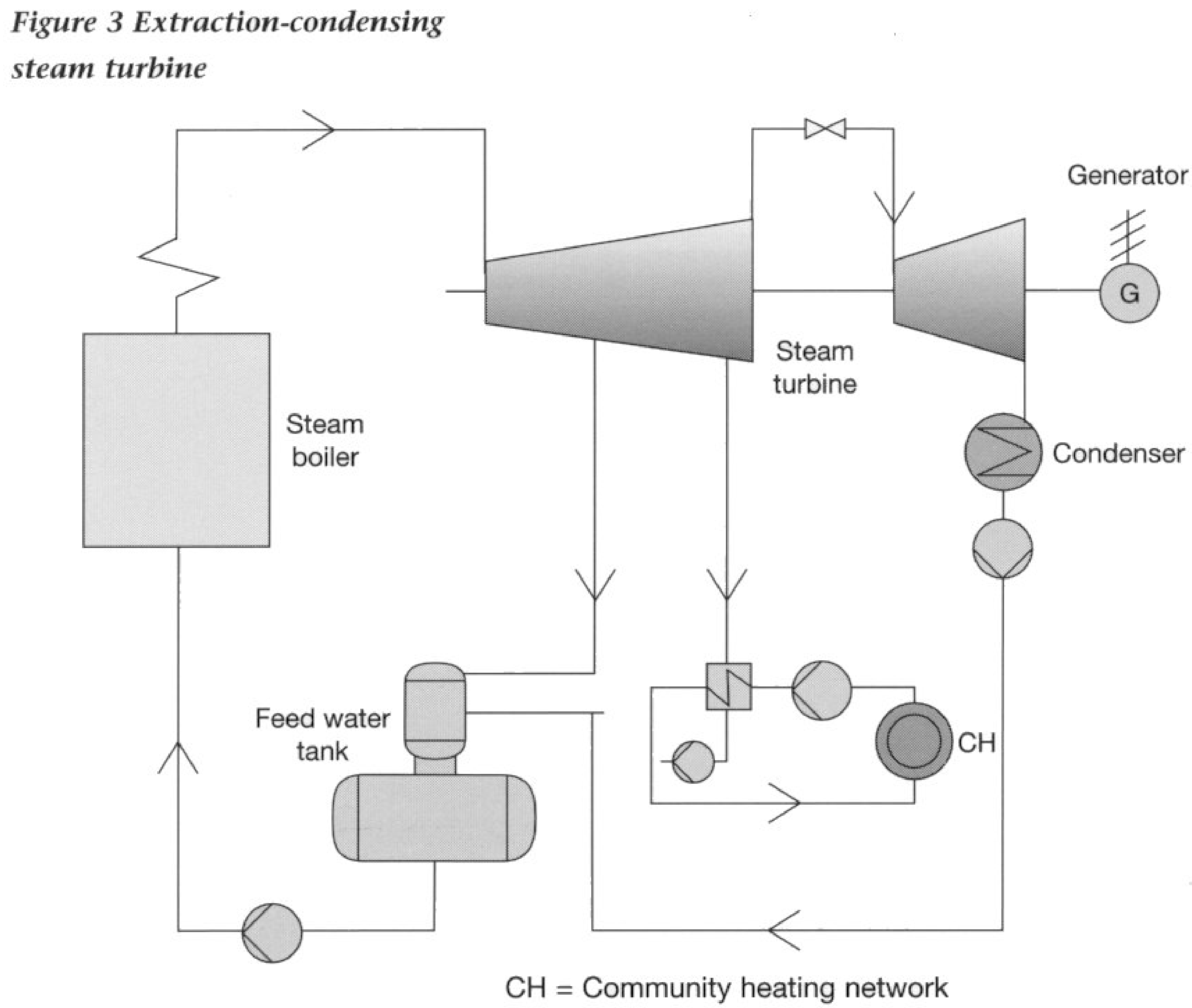


Figure 3 Extraction-condensing steam turbine

3.6.2 Steam turbine plant

The most fundamental design decision relates to the steam cycle for generation of power. More complex cycles involving several stages of superheating and reheating can be justified for large-scale plant and these will operate at steam temperatures and pressures determined principally by material considerations. CHP plant is likely to be smaller, using simpler steam cycles and less extreme steam conditions. The emphasis may be more on achieving high plant availability and low construction cost rather than small gains in the efficiency of electricity generation, because the main economic justification arises from the CHP operation.

The second main design decision is whether to employ a back-pressure steam turbine or an extraction-condensing turbine (see figure 3). Both types are used successfully in CHP schemes.

Back pressure steam turbine

Simple back-pressure sets, using hot water as the primary heat distribution medium, can expand to low pressures and temperatures to give a good balance between power and heat output. Lower back-pressures can be used in the summer when CH flow temperatures can be reduced, giving higher efficiency electricity production. In winter, rejection at higher temperature permits a higher steam flow, increasing the non-specific power output. Auxiliary cooling can be used to dump heat so that electrical output can be maintained in summer.

Extraction-condensing steam turbine

The extraction-condensing plant has a higher electrical efficiency but is more complex. It typically uses two extract points and has the advantage that electrical output can be maintained when the heat load is not available. The extra capital cost for the low pressure turbine, condenser and condenser cooling system has to be recovered by the sales of this additional electricity generation. Figure 3 shows a typical arrangement.

Optimisation

The quantity of electricity produced by a steam turbine, and the efficiency at which it is produced, depends on the temperature (hence also the pressure) at which steam is exhausted from the turbine. The lower the exhaust steam temperature, the more efficient the turbine. High-efficiency turbines exhaust at near vacuum conditions which give condenser temperatures too low for effective CH. In order to distribute and use reject heat effectively, the temperature from the CHP plant needs to be between 75°C and 120°C. To maximise electricity production, the flow and return temperature of the CH water system should be kept as low as possible; a small temperature drop in the network will, however, result in larger, more costly pipes. Hence an overall optimisation is required for the heat distribution system, the consumer connections and the CHP plant (see section 3.3). The CH system should be operated with a variable supply temperature, provided this is always sufficient to meet the actual consumer demand. In practice, the CH supply temperature is varied according to the ambient air temperature. The highest design temperatures are used only to cover the peak demand. Obviously, the steam turbine and adjacent heat generating facilities need to be designed to take full advantage of this temperature variation.

3.6.3 Refuse incineration with steam turbine plant

Local waste disposal authorities will have a refuse disposal policy, which may include incineration. Existing or planned incineration plants represent a major opportunity to develop a CHP/CH project, because most of the cost of the plant will be financed by the refuse disposal contracts and electricity sales. The additional cost to supply heat from these plants is relatively low. Refuse incineration may, under these circumstances, satisfy the requirements of low capital cost and low-cost fuel to meet the base load of a CHP scheme.

Incineration as an initial CHP/CH heat source necessarily means the use of a steam turbine, probably an extraction-condensing set of 10-30 MWe capacity, operating at about 45 bar, 455°C live steam. The use of extraction-condensing steam turbines will generally not be the optimum for a project requiring an electrical generating capacity of less than 10 MWe, as the economics of scale for complex plant do not apply below this plant size.

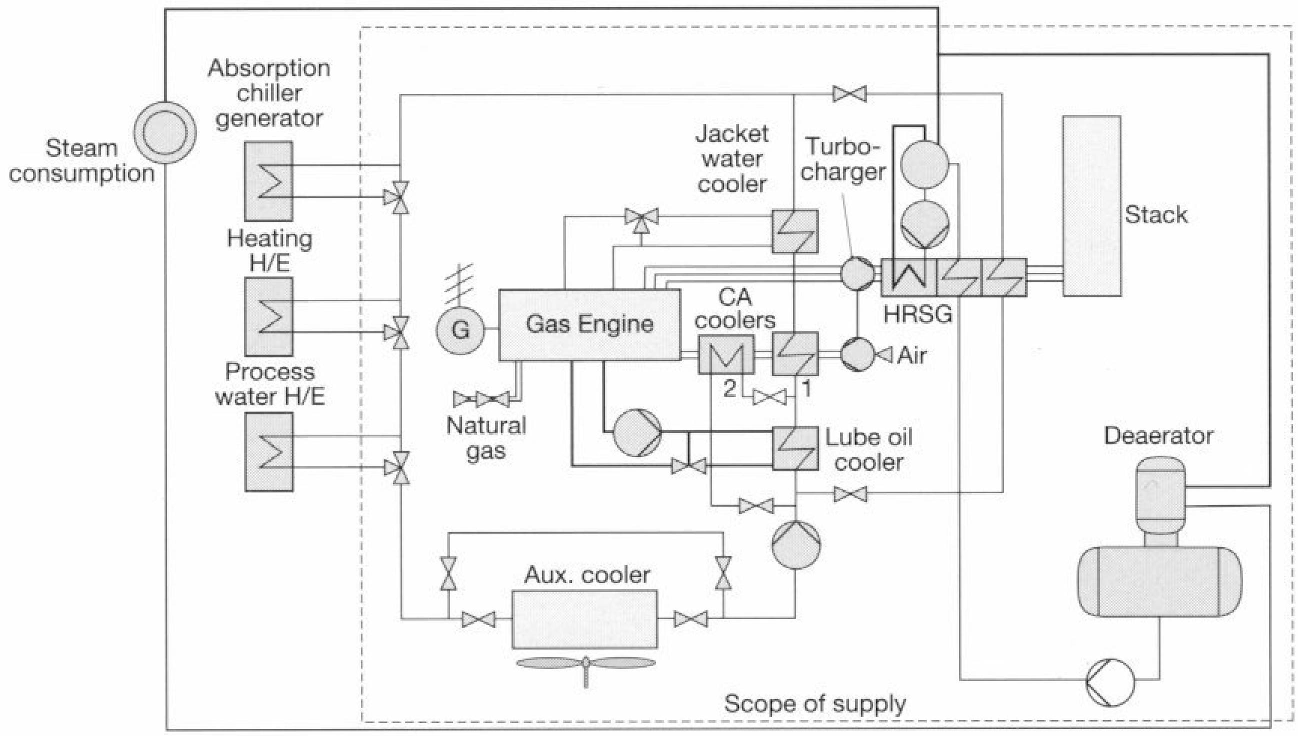


Figure 4 Gas engine CHP (cogeneration) plant

Figure 4 Gas engine CHP (cogeneration) plant

3.6.4 Internal combustion (IC) reciprocating engine generator

IC engine plants (see figure 4) are particularly suitable for operating as base-load units in CHP/CH schemes up to about 10 MWe, where larger development plans are not envisaged. Below 10 MWe, hardly any other CHP options are competitive. Larger capacity IC engines (or multiple engines) can also be applied in larger schemes, where they may compete against gas turbine and steam turbine options.

IC engine plants are typically used to supply the base heat load and are seldom viable if used to supplement a large centralised CHP plant or incinerator, due to the short annual utilisation time.

Heat can be recovered from the exhaust gases, engine jacket cooling water, the lubricating oil cooler and super-charger air intercooler, by a heat recovery circuit. This increases the overall efficiency from 36%-38% for generation only, to as high as 90% if all the reject heat sources are collected to a secondary circuit distributing heating water at about 90^{o}C. Heat recovery is maximised if the return temperature is low enough to recover heat from the turbocharger aftercooler. Supplementary firing can be utilised to give flexibility in operating mode and unscheduled operation.

The costing of heat produced from an IC engine is complex, because heat can be recovered from jacket and oil cooling as well as from the flue gases. Lower return water temperatures will enable more heat to be recovered, so the average cost of heat will be less. If the return water temperature is not low enough for engine and oil cooling, part of the heat needs to be vented off and overall efficiency remains lower. Year-round return

temperatures must be low enough to provide jacket and oil cooling, so IC engines are very suitable for low-temperature heating systems.

The variation in the cost of heat with flow temperature is not significant, as most of the heat is recovered from the exhaust gas path by a waste heat boiler subject to large differential approach temperatures. With IC engines (and gas turbines), heat recovery does not sacrifice power yield, as is the case with the steam turbine process.

Medium speed (500-600 rpm), super-charged compression ignition engines having an electrical rating of 5-15 MWe are well suited to CHP/CH application. An exhaust super-charged engine produces higher exhaust temperatures over the load range, and gives higher efficiency under part-load conditions, than a normally aspirated engine. The heat rejected to exhaust and jacket is almost constant between full-load and half-load and the power generation efficiencies are also more constant at part-load.

Two- and four-stroke engines are available and suitable for CHP usage. In order to select the most suitable prime source recovery plant, full details of relative cost efficiency over the load range, exhaust temperatures, permissible temperature drop in the waste heat recovery boiler, jacket temperatures, and flow rates must be obtained from the engine manufacturer.

IC engines can be adapted for use with a range of fuels, from natural gas to light distillates, and to heavy fuel oil. The latter becomes economical for larger installations, with the lower fuel cost counteracting the additional capital and pretreatment costs.

At a smaller scale, up to 5 MWe, spark-ignition gas engines are available. Although not as efficient as the larger compression-ignition plant, their capital cost is relatively low and they provide the same benefit of good part-load efficiency. They are likely to be preferred to gas turbine plant, provided the return temperatures from the CH are low enough to maximise the heat recovery.

Figure 5 Gas turbine single cycle

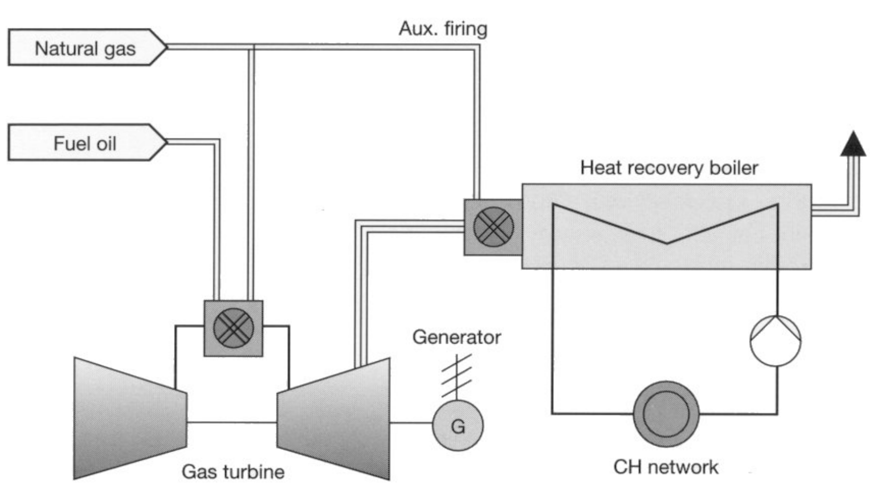


Figure 5 Gas turbine single cycle

3.6.5 Gas turbine/waste heat boiler combination

Traditionally, gas turbines have been used to meet peak load conditions in power systems. However, modern gas turbines (see figure 5) specially developed for continuous operation are appropriate plant for base-load CHP/CH duty as well. Gas turbine and waste heat boiler combinations compete against IC engines in small-scale

CHP (3 MWe to 15 MWe units) and against steam and combined-cycle processes in larger-scale schemes.
Part-load efficiency of the gas turbine is rather low, and full-load efficiency is 30%-35%. Performance data over the whole load range is vital to any design optimisation exercise to determine the detailed CHP plant configuration, cost and operational modes. Excess oxygen in the exhaust gases may support auxiliary firing in the waste heat boilers; which provides an efficient means of supplying peak heat demand.
Design flue-gas temperature is constrained by consideration of acid deposition (if sulphur is present in the fuel), by saturation point and by plume dispersal requirements for planning consent. If a minimum flue-gas exit temperature from the waste heat boiler in a gas turbine configuration is assumed for optimal operation of the plant, the flow and return temperatures will determine the design of the waste heat boiler surface to produce the same degree of cooling the gases. In general, such a cost variation will be relatively small compared to the total CHP station cost, so that for gas turbine single-cycle stations the cost of heat is relatively independent of flow and return temperatures.

3.6.6 Combined-cycle plant

A combined-cycle plant (see figure 6) consists of a combination of different thermodynamic cycle elements and is normally based on using waste heat from a gas turbine single-cycle electricity generating plant, to raise steam and produce further work or electricity from a steam turbine.
The combined cycle process is highly efficient; in electricity-only operation about 50% and in CHP operation as high as 85%.
Excess oxygen in the exhaust gases may support auxiliary firing in the waste heat boilers raising steam for the steam turbine, giving some additional capacity provided that appropriate allowances have been made for the steam turbine and generator. Auxiliary firing is a more efficient method of raising steam than in conventional boilers as the air is preheated.
In assessing the advantages of using combined-cycle plants, the extra capital cost of the waste heat boilers, the steam turbines and the additional equipment needed to install and control two electricity generators needs to be carefully assessed against the value of the extra electricity output obtained. Due to high efficiency and competitive investment cost per capacity (£/kW), combined-cycle plants are commonly constructed instead of conventional steam-cycle plants, where fuels suitable for gas turbines (eg natural gas) are available.
Optimisation of the combined-cycle plant for CHP operation follows a similar pattern to that for steam turbine plant operation, because any heat taken off from the steam turbine will result in a reduction in electrical output. However, in CHP operation about one-third of the heat recovery can be obtained from the gas turbine waste heat boiler, at a temperature well suited for CH supply but not adequate for steam raising for the turbine and thus not sacrificing the power yield.

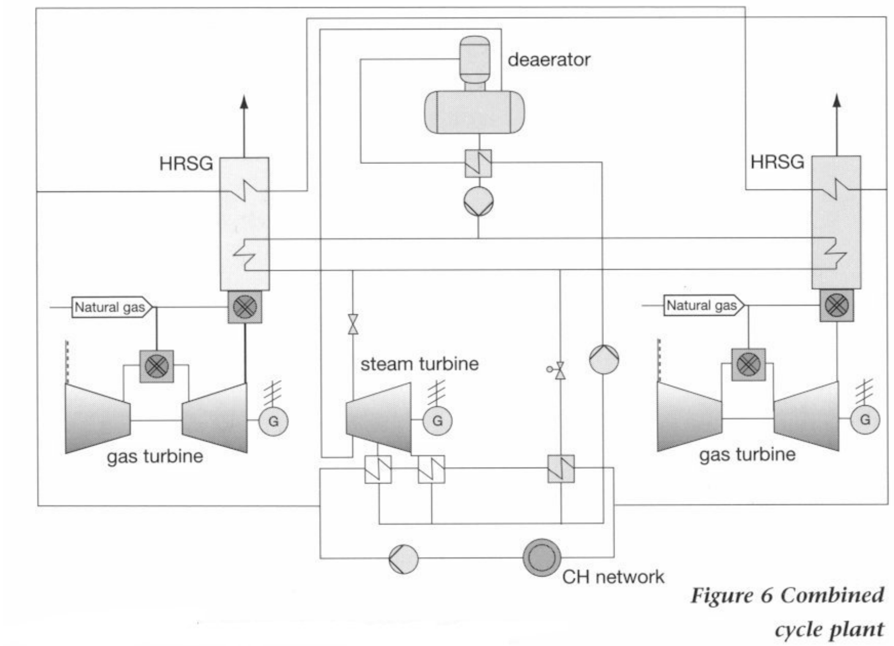


Figure 6 Combined cycle plant

3.6.7 Peaking plant

Peaking (and reserve) plant will generally be the most flexible low-capital-cost boiler plant obtainable. Peaking boiler plant can be installed centrally, alongside the CHP plant. Alternatively, it can be distributed in smaller modules, local to major consumers or areas of load throughout the CHP/CH scheme.

Centralised heat-only boiler plant has the following advantages:

- economies of scale
- lower operation and maintenance costs
- simpler centralised pumping and pressure control
- centralised supply temperature control
- price advantage in boiler fuel supply
- diversity of demand can be utilised to reduce installed capacity
- centralised temperature boosting during peak demand to keep temperatures on to the steam turbine condensers as low as possible.

The distributed arrangement has the following advantages:

- use of existing boiler plant within former group heating schemes or large buildings to reduce capital costs
- flexibility of scheme development
- improved security of supply against the failure of a major heat main
- reduced costs of the major heat mains which, with local peak duty boilers, can be sized somewhat smaller (provided that the carrying capacity of the heat main still

enables maximum use of CHP heat)

- lower pumping energy and heat losses (although electricity costs at remote pumping stations will be higher than at the CHP plant)
- local flow temperature correction to allow for losses in distribution
- local temperature boosting for buildings that require a higher flow temperature than the optimum for CHP plant operation may permit lower distribution temperatures to be used.

In practice, any larger CHP/CH scheme is likely to incorporate a mixture of central and local boiler plants. Large CHP projects with long-distance transmission from remote generation plants would be unlikely to use central supply temperature control, as very large networks may be fed by more than one CHP plant. Although the different plants have their own temperature control, common practice is that the temperature difference between plants feeding the same network should not exceed 10°C. The temperature is controlled individually but the instructions are given by the main plant. The main reason for this is to avoid temperature and pressure fluctuations that can shorten the life of the distribution system.

3.6.8 Use of thermal storage

There are two principal reasons for using thermal storage in conjunction with CHP systems:

- to enable the CHP plant to maximise electricity revenues
- to enable fuel use in peak boilers to be minimised.

There is also the advantage that some reserve capacity' is likely to be available from the thermal store to help meet a short-term rapid increase in demand.
The most common applications are as follows.

- ***For extraction/condensing-type steam turbine.*** The thermal store is used to supply heat during periods when the electricity price is high, so that the turbine can run at maximum power without extraction of heat, thus maximising electricity revenues. Conversely, heat can be produced from the turbine at times of low electricity prices.
- ***For back-pressure steam turbine, gas turbine or IC engine CHP plant.*** The CHP plant is operated at the times when electricity prices are highest and the surplus heat is stored for use at night when low electricity prices mean that it is uneconomic to run the CHP plant. This minimises the fuel use in the peak boilers.

Thermal stores may be pressurised or unpressurised; with the latter an upper limit of 98°C is feasible. Determining the storage volume of the heat accumulator is a complex optimisation process for which computerised simulation models have been developed. The selection of storage temperature can be considered independently from the distribution temperature as part of the optimisation of the storage system. The lower the design return temperature the better viability can be achieved for the accumulator as the energy storage capacity will be higher for a given volume. The heat accumulator can also be used for pressurising the community heating system.

3.7 HEATING DISTRIBUTION MAINS

3.7.1 General

Heat distribution pipes are normally designed as a bonded pre-insulated piping system suitable for a directly buried underground installation. This type of pipe system is covered by four European standards (see section 5.2).
The pre-insulated bonded piping system, according to the above standards, consists of a steel carrier pipe designed for 16 bar operating pressure, with polyurethane (PUR) insulation with zero ozone-depleting (ODP) gases and a high-density polyethylene (HDPE) casing, all bonded together. This arrangement means that thermal forces and movements in the ground will be converted to friction between outer casing (HDPE) and surrounding soil.
All mains components, contents pipe, insulation and outer casing are bonded together and will move together as one composite system against the frictional resistance of the ground. Each component exerts forces on the adjacent component. The whole system must be able to move as intended and resist without failure all internal and external forces that will arise from the operating temperature and pressure modes.
Modern pre-insulated CH mains are suitable for even higher temperatures than 120°C (up to 140°C for short periods), but this is not usually economical for CHP/CH. The duration of operation at temperatures above 120°C must be compatible with the temperature-time aging characteristic of the insulation (refer to standard EN 253, see section 5.2).
Normal free expansion is resisted and reduced by friction between the outer casing and the ground. Some advantage can be taken of this to reduce (friction restricted installation method) or fully restrict (friction fixed installation method) maximum movement due to expansion. However, the frictional resistance of back-fill varies with the type of material and adjacent ground conditions, and adequate margins should be allowed for this variation in adapting ground frictional resistance assumptions. Various construction processes, such as ‘cold draw’ and ‘preheat’, are commonly used to induce (pre-stress) forces, in order to counteract expansion forces. Mains can be preheated by the use of temporary boiler plant, electrical resistance, or induction methods, or by mechanical stretching before the final closure welds are made. This puts the contents pipe in tension at ground temperature and reduces the amount of expansion and forces due to expansion at the operating temperature. The required preheating can be compensated with once-acting compensators that are welded after the first heating. This method has the advantage of being able to backfill the trench freely immediately after mechanical installation and inspection. Provision for expansion by specific expansion lops, bellows and padded bends can be minimised. Anchors are also minimised and must be designed, located and constructed to ensure that the expansion and consequent forces arising in the system are constrained to the design configuration.
Because the axial forces are very large (the thermal expansion force for DN 400 pipe is 100 tonnes when the temperature difference is 50ºC), the system should be designed by the specialist, and special attention must be paid to all bends, branches and entry points.
The moisture detection system and fault locators are normally supplied by the manufacturer. Generally the moisture detection system should be a simple (two wire) and reliable system, with fault locators indicating the type of fault and its. location. It can be designed to give alarm through a remote operation system, but in most cases a local alarm and fault locator system is sufficient. If there is moisture in the PUR-insulation the action required is normally not urgent.
For low-temperature networks, pre-insulated all-plastic piping systems are available;

these are suitable for conditions up to 90°C and 6 bar. These systems are supplied as coiled pipe up to 50 mm (and in straight pipes up to 200 mm). This piping system can be suitable for small local CH schemes, if there are no plans for extensive future expansion, when the above pressures and temperatures could become a limiting factor.

3.7.2 Pipe sizing and network design

Sections 3.2 and 3.3 discussed the optimisation of system temperatures and pressures. Once the temperature differential at design condition and the maximum and minimum pressures on the network have been optimised, the network design, which specifies the pipe sizes for each branch, can commence.

In common with other fluid distribution systems, the selection of pipe or duct sizes and operating pressures is based ideally on an economic optimisation. If the size of the distribution pipes is decreased to reduce capital costs and heat losses, pressure drops increase and total pressures rise requiring higher pump energy and higher running costs. There is, therefore, an economic optimum when total life-cycle costs are minimised.

Economic optimisation involves the evaluation of three costs:

- capital cost of distribution mains and system pumps
- pumping power
- distribution heat loss.

Since both capital and annual running costs are to be considered, a discount rate and time horizon need to be selected to permit a life-cycle cost to be determined.

For simulation and dimensioning of complex networks, computerised simulation programs are recommended. The dimensioning criteria will have small variations from case to case. A simple rule can be given as a pressure loss of 1.0 bar/km for transmission lines and 2.5 bar/km for branch lines. Special attention should be paid to the dimensioning of the pipeline supplying the index circuit reference consumer because that line will have the full influence on pumping costs. Branches which do not affect the index circuit can often be sized smaller to minimise capital costs without affecting pumping costs.

In principle, separate optimisation is required to determine the optimum thickness of insulation, balancing the additional capital cost of thicker insulation (including the necessary increased trench width) against the savings in fuel costs. In practice, for the sake of economy, one of a limited number of insulation thicknesses available in standard products would generally be used.

3.7.3 Detailed design

The detailed design of underground CH piping is a specialised field and after sizing and optimisation of the network, an experienced and competent designer should be employed.

The pipeline should normally be designed in accordance with the recommendations of the manufacturers and the EN standards. Special attention must be paid to anchoring, branch points, horizontal and vertical bend points, and entry points into the building. Also, the selection of installation method and special requirements of the installation method (friction fixed or friction restricted), thermal expansion and movements must be designed.

Preinsulated piping systems with an HDPE casing do not require a cathodic protection system.

A minimum separation between the heat mains and other underground services (electricity, telecommunications, mercury, fibre optic cables, water mains, gas mains, sewer lines, etc) should be provided. Where heat mains are to run in parallel with electrical cable, the electricity company should be consulted, to agree an appropriate separation to avoid overheating the cable.

The selection of an appropriate method for forming insulated joints is an important part of the design process. For smaller sizes, taper lock or shrink sleeve types of casing joints are acceptable, but for larger sizes (DN 250 or larger) PE-welded casing joints are recommended.

The design will also include mechanical and civil design of all necessary details such as manholes, anchor points, air vents, drain point, and entry points.

The result of the design should be:

- site plan drawings at 1:500 or 1:1000 scale
- detailed drawings at 1:20 or 1:50 scale
- pipe route profile in scale 1:100/1:1000 (vertical/horizontal) including crossing services and other important information.

3.7.4 Site supervision and installation

High-quality installation is essential, because any repairs to buried heat mains will be expensive and will disrupt the heat service. It is recommended that the work is carried out under a quality assurance regime with site documentation of all critical inspections and operations. Errors may not emerge as problems for many years and to minimise them it is very important to have experienced and competent supervisors and fitters together with representatives of the CH company on site at all times.

The installation quality specification should define the key principles and inspection stages to be employed.

Key principles:

- definition of each trench section and how many may be open simultaneously
- special requirements of highway authorities and police
- which inspections are to be in the presence of the client or other parties (highway authorities, owners of other services).

Inspection stages:

- the location and inspection of other services
- setting out
- trench excavation
- sand bedding
- pipe laying and welding
- casing joints
- sand back-filling
- road layers
- final acceptance
- end of warranty period.

Especially important is the inspection and air-testing of casing joints. The casing joints are recommended to be tested by 0.2 bar g air pressure and soap liquid (note that for some joint types this air test is not technically possible). According to statistics from

other countries 50% or more of failures found during operation in pre-insulated piping systems are caused by leaking casing joints.

During the installation of the pipeline it is likely that underground obstacles not shown in records will be encountered. These will necessitate design changes that will need to be made quickly on the spot, and this requires the presence of a competent supervisor on site.

Normally it is also the duty of the contractor to make as-installed drawings. These are important for later operation and maintenance and to minimise the risk of third-party damage. The drawings should be deposited with the highways authority in accordance with the New Roads and Street Works Act (1991). Accurate as-installed drawings are also important when using a moisture detection system. The drawings should show the exact location, connection and length of each section, the location of possible relays and fault locators and the location of special risk points such as casing joints, bends and Ts.

3.7.5 Moisture detection system

It is good practice to purchase the moisture detection system from the pre-insulated pipe manufacturer.

The moisture detection system will include an alarm and signal wire system, necessary relays and fault locators.

The contractor should prepare detailed installation drawings for the moisture detection system.

In the design of the moisture detection system it is important that sufficient provision is made for future expansion of the network.

3.7.6 Commissioning

Commissioning the distribution system includes commissioning the pipeline itself, valves, drains and vents, and the moisture detection system.

During commissioning, the pipeline should be flushed properly, and during its first heating thermal expansions should be checked to ensure that they are as designed.

The commissioning of the moisture detection system should include a loop test, a resistance test and a short cut and broken wire test. It is very important that all tests and commissioning results are properly recorded.

3.8 CONNECTION AND CONTROL OF CONSUMER HEATING AND HOT WATER SYSTEMS

3.8.1 General

The connection and control of consumers' systems generally divides into three categories:

- consumers served from small hot water heat distribution systems with direct connection method (see figure 7a)
- consumers served from hot water heat distribution systems with indirect connection method (see figures 7b and 8)
- consumers systems, industrial and institutional, served from steam distribution networks.

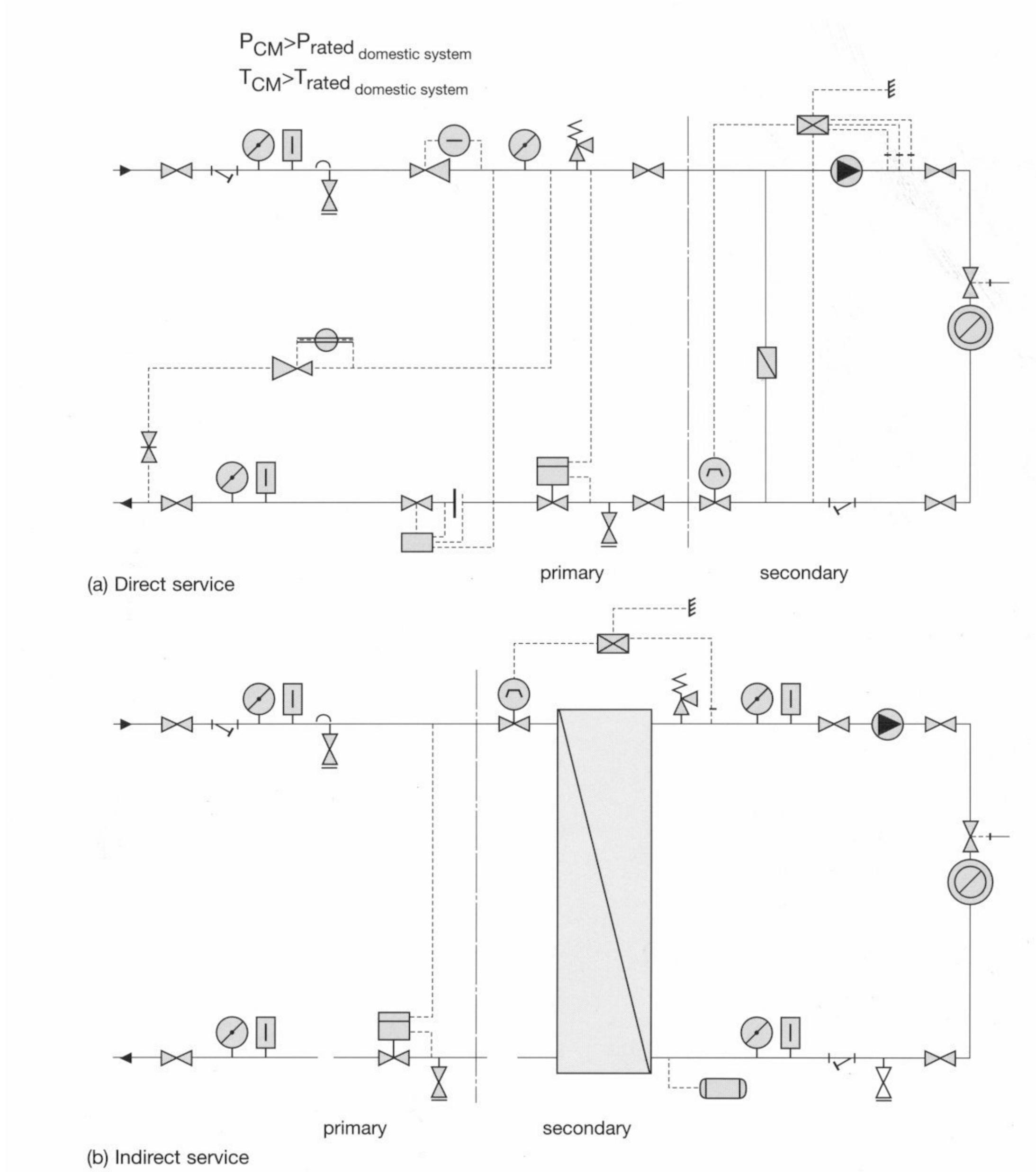


Figure 7 Layouts for service installations

†CM: Community (heating) main

Figure 7 Layouts for service installations

Hot water distribution networks are the principal means of heat distribution from utility CHP/CH systems. Consumer systems served from steam networks are included for completeness, although such systems are likely to form a discrete CHP/CH system rather than be part of a mixed-load system.

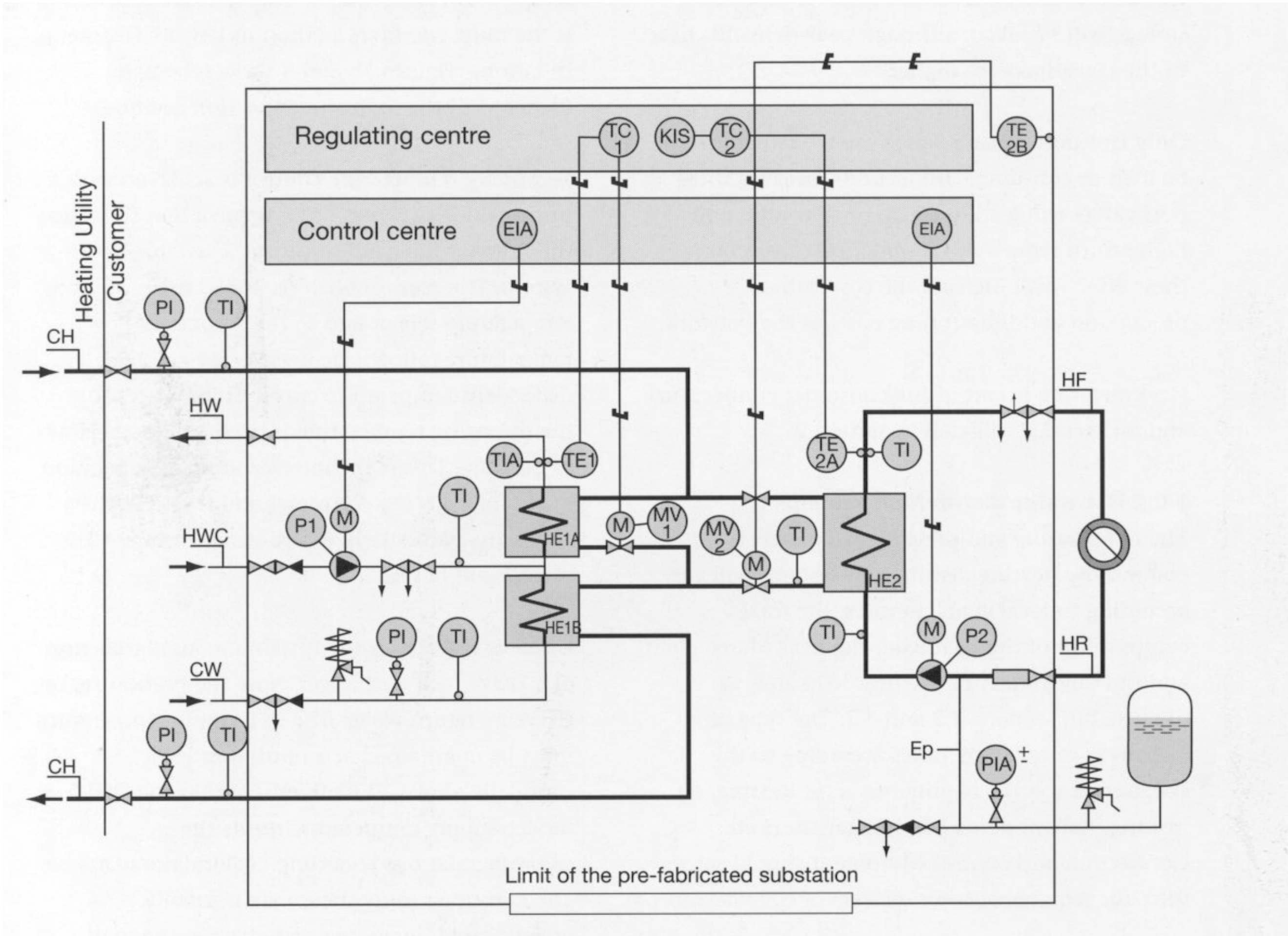


Figure 8 Basic connection scheme

Regulation of domestic hot water temperature

Regulating centre TC 1 regulates the motor valve MV 1 according to the measurement of temperature sensor TE 1 maintaining the temperature of domestic hot water at the right level. The recommended value is 60ºC

Regulation of heating network temperature

Regulating centre TC 2 regulates the motor valve MV 2 according to the measurement of temperature sensor TE 2A holding the flow water to the heating network in accordance with the set value.

The most important requirement of the connection method and the secondary system design is to reduce the return temperature as far as possible. This leads to lower flow rates, and lower network costs. The design of the internal heat distribution system of the building should be reviewed in detail in order to improve the cooling of the community heating water. It is recommended that the CHP/CH company should retain the right to review and comment on the design of the connection method and secondary heat distribution system. This will ensure that the new consumer will be connected correctly to the CH system and that cooling and temperature levels are suitable to the particular CH system.

The DHW connection to the CH system should preferably use the instantaneous heat exchanger connection method (see figure 8). This method improves the cooling and is also more economical for the consumer when heat losses from DHW storage will be saved, although peak demands near to the consumers are higher.

Only two-port control valves are recommended to be used in consumer connections, because three-port valves will lead to constant flow rates and high return temperatures under part-load. Both of these effects will increase the cost of heat production and the running costs of the network.
Heat metering is part of the consumer connection and is described in detail in section 2.

3.8.2 Hot water distribution systems

The temperature and pressure parameters of community heating distribution systems will vary according to local characteristics, the total composition of the heat load, the heat source plant and the topography of the heat load area, as discussed in sections 3.2 and 3.3. The type of consumer installation varies according to the consumer's specific requirements for heating, air heating, radiant panel heating, radiators etc. Connection and control equipment should satisfy the basic requirements for each set of circumstances.
Consumers receive heating from a flow and return system delivering water at either constant flow temperature or at a scheduled variable flow temperature to all elements of heat load, whether used for heating or DHW production. Normally the operation of the distribution system is designed to follow variable temperature and variable flow systems. This is the case especially in large CHP/CH systems, although constant low temperature distribution systems can be viable in small community heating systems, where heat is produced by waste heat from CHP IC engines.

3.8.3 Indirect connection method

Indirect connections separate the internal heating circuits of the building from the community heating system. This allows freedom to select pressure and temperature levels for the CH. Indirect connection is the most common method in larger CH systems in Europe. Figures 7b and 8 show schematic diagrams of the indirect connection method.
Secondary temperature control is achieved with a primary side two-port control valve that throttles the primary flow and results in a variable-flow system. The control board is linked to an outdoor temperature sensor and so the secondary flow temperature follows the preselected ambient dependent temperature curve. This ensures that the operating temperature is adequate, but as low as possible. This is the most economical operation mode for both the consumer and the CHP/CH company, particularly where steam turbine CHP plant is employed.
Figure 8 also shows the instantaneous connection of a DHW heat exchanger. Note the preheating of DHW by return water. The CH supply temperature must be maintained at a minimum level (normally above 70^{o}C) to ensure that the DHW service supply temperature meets the recommendations regarding Legionnaire's Disease. The consumer units shown are normally prefabricated, including plate heat exchangers, controls, wiring, and pumps, so the on-site installation is quick and economical.
The terms and conditions of the heat contract and tariff should encourage the use of controls that minimise the peak demand and encourage the return of water at low temperature by financially penalising the use of an unnecessarily large quantity of primary water. This will lead in the long term to consumer controls compatible with the economic objectives of the CHP/CH system.
Radiator/convector heaters served from a centralised temperature-compensated system should be fitted with individual thermostatic radiator control valves (TRVs). TRVs should incorporate a suitable presetting facility — this will depend on the design temperature differential and flow rate of the radiator/convector.

3.8.4 Direct connection method

The direct connection method (see figure 7) is normally used in smaller community heating systems without any expansion plans. In large systems the direct system could become a limiting factor for expansion.
The direct connection method is used in CHP/CH systems where low temperature heat is available and essential for economical heat production. This kind of system can be supplied for example, from an IC engine CHP plant. The heat supply temperature to a dwelling heating system should not exceed 90ºC and the pressures will need to be compatible with the radiator system.
Temperature control by means of TRVs is recommended for the direct connection system, and the use of the presetting valves will enable low flow rates and large temperature differentials to be obtained. A fine mesh strainer is required to protect the small openings within the TRVs.
To limit the maximum flow rate to any circuit and to ensure that the TRVs can shut off, it is necessary to control the differential pressure across the circuit. This is achieved by a direct-acting differential pressure control valve which operates by means of a pressure diaphragm and a spring controlling the closing action. These devices are robust and reliable and are recommended to improve the balancing and control of temperatures, even for small systems.

3.8.5 Steam systems

The most common heat distribution system is the hot water system; steam is normally used only for consumers who need steam for their process or who require higher temperatures.
Steam systems are appropriate for industrial areas with significant process steam demand, and for institutional buildings with large space heating, cooling, hot water, sterilisation or laundry loads, provided these steam loads are located within economical transmission distance of the CHP generating station.
The characteristics of steam distribution systems are not presented in detail in this Guide, because each steam system has its own individual requirements, and needs to be a bespoke design.

3.8.6 Heating service accommodation requirements

Equipment for the termination of the utility system and central control equipment for large commercial or communal heating consumers installation should be accommodated in a room allocated specifically for the purpose. The room should be as close as possible to the point of entry of the utility supply system and be lockable, giving access only to authorised consumers and heat utility operators. The entrance and exits should be clearly signed. Independent external access is preferable, and the room should be located to avoid noise nuisance to adjacent dwellings. The room should be adequately ventilated and the ambient temperature should not exceed 40ºC.
Safety notices appropriate to the type of equipment installed (ie steam, isolation of LV hand tools, etc), must be prominently displayed.
The room should have adequate lighting and an electrical supply for pumps, controls, small power tools and for the heat meter, and be equipped to terminate all necessary control and monitoring cables.
For large systems, room drainage should be provided with a door threshold to prevent escape of water into the building on drain-down.

3.9 CIRCULATION PUMPING AND PRESSURISATION

3.9.1 Introduction

CH water systems need to be kept full of water at all times, in order to give satisfactory circulation. The fluid (water) must be at positive pressure in all parts of the system to prevent cavitation and evaporation, which can lead to problematic water hammering. A static pressure has to be maintained to meet this requirement.
The static head or pressure for a CH system is usually created by the use of constant running pumps. Static head can also be created by a header or accumulator tank at the appropriate level.
It is recommended that the expansion tank and pressurizing system be designed as a closed system, where air will not be in direct contact with CH water. This is normally done by using slightly over-pressure steam or nitrogen in the top part of the expansion tank.
A CH system has to satisfy a heat load that varies from maximum heat demand and system heat losses to system heat loss only, which may be in a ratio of 12:1. This requirement is fulfilled by varying the quantity of flow and/or the temperature difference between the flow and return CH water. For efficient CHP operation the CH return temperature should be kept as low as possible. The flow temperature can be varied with the outside temperature to meet the variation in the space heating demand.
Domestic hot water (DHW) demand is not related to outside temperature. It can be met only by keeping the flow temperature above the minimum required for the domestic hot water heat exchanger (storage or instantaneous) to give hot water at a desired temperature above the safe storage temperature and in the quantity required. Air heating battery supplies generally need to be at constant secondary flow temperature, so the water flow circulated has to be varied to meet the load variation. The size of the conveying pipe system will be fixed in size, so a variation in mass flow can be achieved only by a change in water velocity. The circulation pumping system is needed to overcome the total frictional resistance for any flow condition and to maintain the required minimum pressure difference at the reference consumer (see figure 9).
Two fundamental arrangements can be used to meet the variable mass requirement, constant or variable speed pumps. The most common and economical is variable speed control pumps. In order to do this the pressure is monitored at that point in the water path which has the biggest frictional resistance at the full load condition (the index circuit).
To ensure that each consumer connected to the CH network receives the required amount of circulated water over the load range, it is necessary to provide a means of regulating the volume of water flowing through each connection. In the indirect connection method, two-port valves will, together with the monitoring of the index circuit, automatically keep the system in balance and facilitate the use of variable speed pump drives, thereby saving energy. The control valve must be selected to take account of the typical local system differential pressure. In special cases differential pressure control valves may be needed to provide greater security in limiting peak flow rates. With the direct connection method, differential pressure control valves will maintain similar conditions for each consumer.

3.9.2 Pressurisation

The pressure control arrangement establishes the required pressure level and, in the event of the circulating pumps shutting down, this ensures maintenance of a specific above-atmospheric pressure. The static pressure must always be above the saturated

steam pressure of the heating water at any point of the water circulation system. This also applies to the working pressure when the circulating pumps are running.

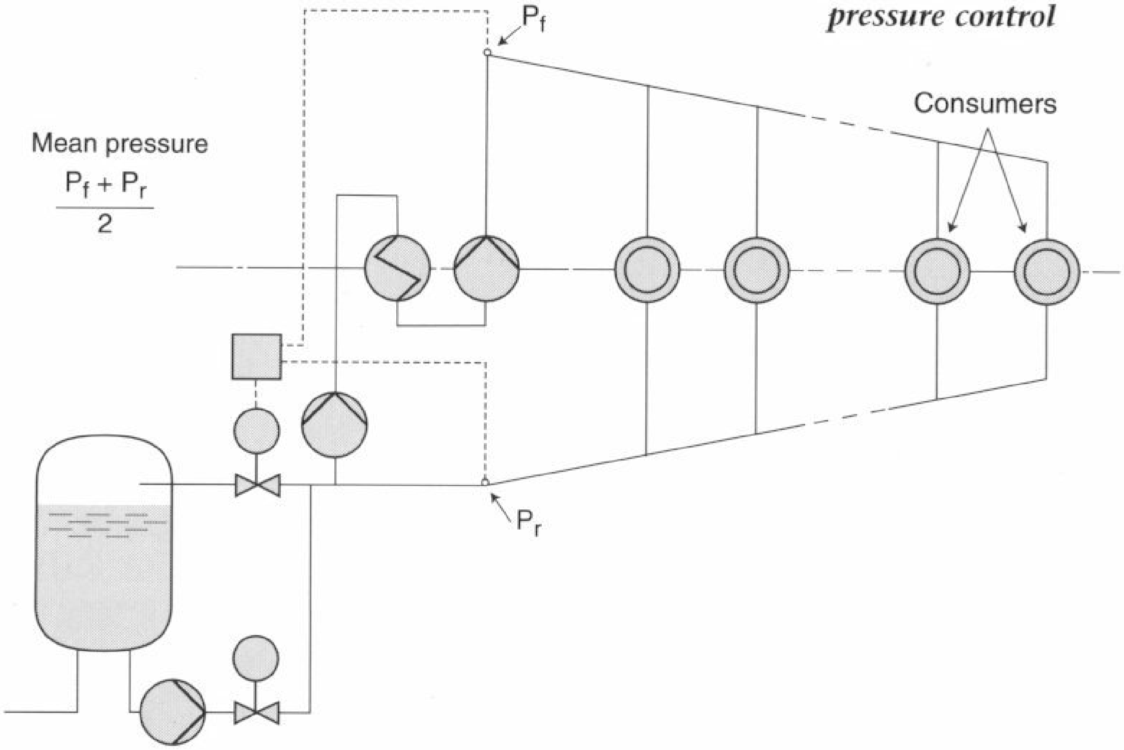
Pressure is normally maintained by a pressurising pump set to pump make-up water from the expansion tank to the community heating system. The expansion tank is normally of a closed type where air contact is prevented by low-pressure steam or nitrogen. Figures 9 and 10 show the principle of a typical CH pressurising system. The pressure in the system is controlled by pressurising valves.

The mean pressure control shown in figure 9 is commonly used in large systems and leads to minimal pressure variations in the distribution network, resulting in a longer life and more trouble-free operation of the system.

At the point of connection of the pressurisation unit to the circulating water system, the system pressure is fixed at the static head pressure. At this point (the neutral point), the static head pressure is the total pressure of the system. At all other points the pressure at any one point will be the static head plus or minus the pressure due to the pumping pressure gradient, and differences due to elevation.

If pressure pumps are used for static head margin, careful design is needed to achieve 100% continuity of pumping, covering pumps and electricity supplies. Failure of margin results in cavitation in the network and the risk of water hammering, involving long outage before restoration of normal supplies. Cavitation causes wear, and the collapse of cavitation gives rise to pressure surges. For a system temperature of 80^{o}C the saturation pressure is 0.47 bar a, while for the higher temperature of 120^{o}C the saturation pressure is 1.97 bar a, and a margin of 0.5 bar may be applied.

Figure 9 Mean pressure control



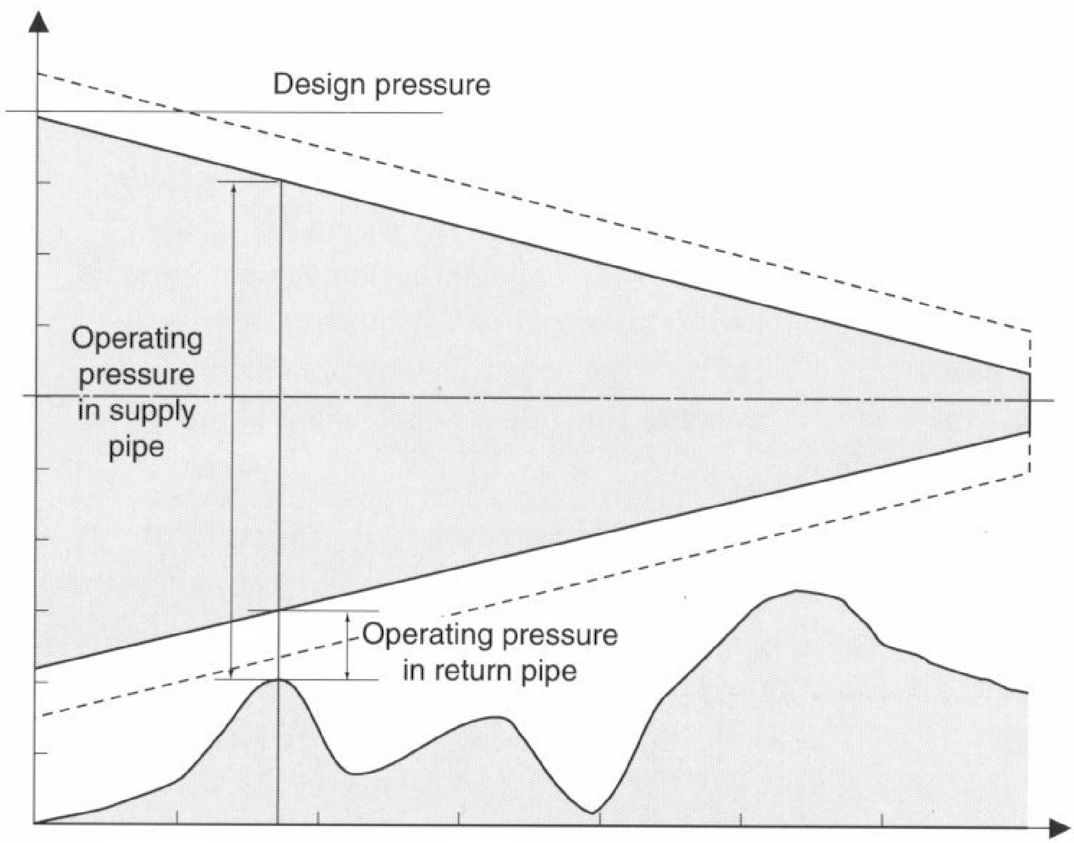


Figure 10 CH network pressure diagram

Figure 9 Mean pressure control and Figure 10 CH network pressure diagram

3.9.3 Circulation pumping

The circulation pumping system is required to provide sufficient pressure to overcome the frictional resistance and the required minimum pressure difference of the mains network at the design flow.

The capacity of the circulating pump system should be based on the volume of water required to meet the system's maximum demand, with a standby pump capacity sufficient to cope with the outage of the largest pump unit. Variable speed centrifugal pumps are generally used.

Pumps are run singly or in parallel to meet increased volume demand. Pumps in series are used to meet increased pressure requirements.

Pumps are run to the demand of control points in the network, usually the index circuit (normally the pipeline to the most hydraulically remote consumer). The resistance of individual load circuits will probably be met by local substation pumping in larger systems, and control may best be effected by maintaining a constant pressure differential in each sector of the main distribution.

As the selected mains diameter is reduced the pressure necessary to provide the flow will increase; this must be addressed at the design stage. The mains costs will decrease with smaller diameters but the pumping power costs will increase with higher required pressures, assuming the same rates of flow. Thus the starting point for determining the system pressures involves finding the minimum total cost system. To determine the total cost, both mains capital cost and pump running costs must be considered. Optimisation should be based upon the maximum hourly load.

For extensive networks the total cost consideration may give an unacceptably high pressure at the pumping station, assuming the network is pumped from one location. However, the optimum can be achieved by using more than one pumping station, permitting high pressure gradients and smaller pipes to be used but ensuring that the total pressure does not build up to an unacceptable value at any point in the system. So in large systems with long transmission lengths, pressure booster stations may be required to ensure the correct water circulation and pressure difference is available at the most remote point of the system.

The topography of the area must be considered — the head requirements for load circulation, vaporisation margin and source pressure drop being satisfied at all points by the pumping pressure, as indicated in figure 10.

The maximum pressure limit in a system is imposed by the strength of the components in the circuit. Assuming direct connection of the consumer system to the utility system, the most critical components are the panel radiators. These normally have a maximum permitted working pressure of 6 bar, but pressure limits can go down with age, so this should be reviewed as the system ages. The indirect connection method gives more freedom for the selection of economical pressure and temperature levels. A minimum pressure limit also arises because the mains pressure should not be allowed to fall below the saturation pressure of the water, otherwise cavitation occurs. The system static head must prevent cavitation at pump suction positions and at the highest points in the system.

The pressure limitations should be checked against a number of operational cases:

- system running under design conditions
- zero flow condition with the pumps running
- zero flow condition with the pumps off

- transient flow conditions and pressure surges.

In all cases the relevant limiting component working pressures should not be exceeded at any point in the system. If safety valves and pressure-reducing stations are used to connect high and low pressure parts of a system, these must be of a fail-safe type. This applies equally to direct and indirect systems.

Pump sizing for CH, as in all pump applications, is based on the pump characteristic and the system flow friction loss characteristic. This operation at minimum energy usage is a significant aspect of system pumping and makes variable speed pumping virtually essential.

Figure 11 illustrates the relative power requirements for the alternative methods of flow control, throttling or variable speed. Peak power demand is of short duration, so operation at reduced speed represents a large saving in energy.

Figure 11 Relative power requirement of constant and variable pump control

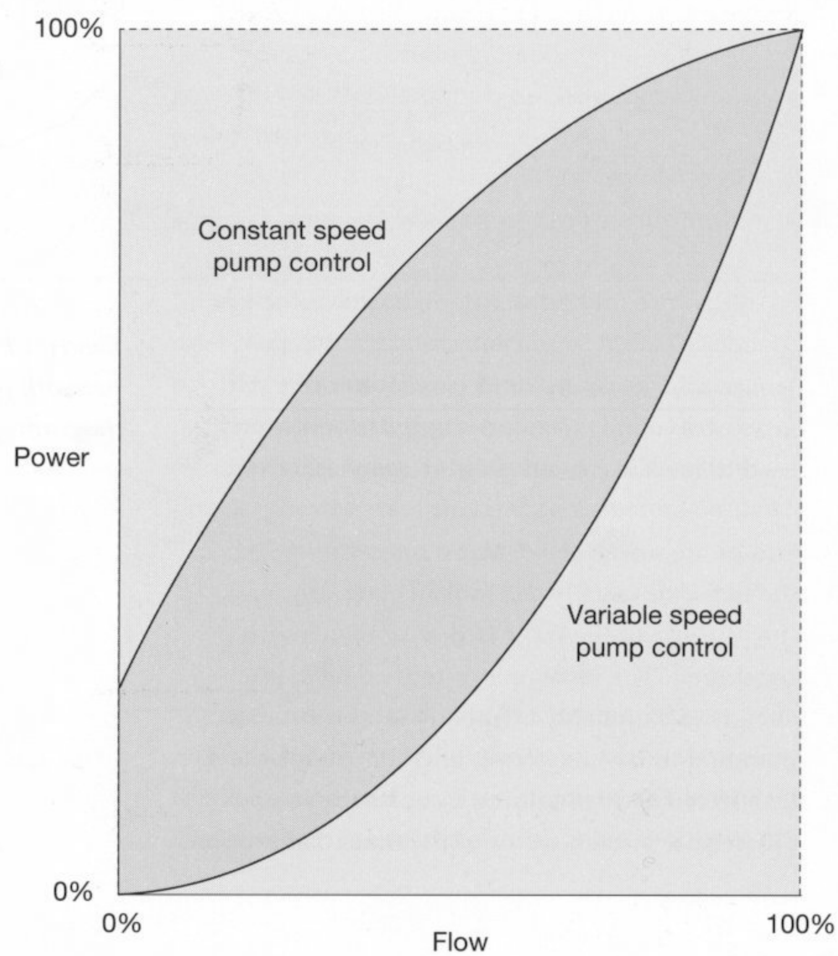


Figure 11 Relative power requirement of constant and variable pump control

Variable speed pumping also offers an improvement in motor life and reliability. Bearing

wear is less at reduced speed, as is bearing load, the absorbed power having been reduced. Because of the reduced load, the windings will also run cooler and generally have a less onerous duty, but this depends on the electrical characteristics of particular methods of achieving variable speed.

3.9.4 Load control

In large-scale hot water distribution systems, two-port control valves and variable flow may be used to control the heat delivered to individual loads or groups of loads. This offers three major advantages over the alternative three-port valve control under constant system volume conditions:

- lower capital cost
- significantly reduced pumping cost due to reduction of flow under part-load operation
- lower return temperatures under part-load, resulting in lower heat losses and better CHP plant performance.

Modern two-port valves are able to operate without problem up to 5-6 bar pressure difference over the valve. The centrifugal pump characteristic pressure will increase as the valve begins to close, and the valve authority will vary continuously over a wide range. It is therefore necessary to provide a variable flow pumping system to maintain pressure conditions within acceptable limits for each substation and secondary circuit. Variable flow water circulation systems have slightly higher capital costs than constant volume pumping systems. However, the great advantage of the variable flow systems is the high energy saving in system pumping, and so accordingly the operation costs are much higher for constant rather than in variable flow operation. Two-port valves themselves represent a throttling energy loss, but facilitate reduced system flow volume to meet reduced load requirements.

3.9.5 Methods of circulation pump control

Variable speed pumping

The most common method of pump control is variable speed, where the head of the pump is controlled, and to meet the required minimum pressure difference at the index consumer (usually the consumer most remote from the plant). Other controls, such as throttling controls, are no longer used for new plant because of their high energy consumption. Variable speed pump control is used, combined with two-port controls, at consumer substations.

The pump head is controlled by the pressure difference control system, but the consumer control valves govern the flow. The temperature of water leaving the plant affects the flow required to satisfy consumers.

The bypass control is not recommended. Although shunt bypass differential pressure control offers a means of reducing the pressure variation with load at any specific position along a distribution network, it maintains a constant flow in the system and raises the return water temperature, which is undesirable for CHP/CH.

The need to limit flow variation and temperature gradient through some heat source plant should be met in a manner that retains low flow and return temperatures to steam turbine plant.

The principal system temperature operating regimes of the CHP/CH system, ie variable flow temperature and constant flow temperature, inherently give rise to volume variation with load. Variable volume pumping is necessary to pump the variable load efficiently.

Variable volume can be achieved either by variable speed pumps or by a series of fixed pumps operating in parallel. The demand for change in pumping capacity (number of pumps) and pump speed is controlled by the differential pressure at the index current or across the load branches. Fixed speed pumps run at the pump characteristic pressure volume position appropriate to the volume demanded by the load and regulated by throttling at control valves.
The variable pump speed is regulated by a differential pressure controller installed across the index circuit; this maintains a constant differential pressure under all load conditions.
It can be seen from the pressure distribution diagram in figure 10 that if the pump speed is varied to give an adequate differential pressure at the index circuit, then the circuits nearer to the pump will have sufficient pump pressure available under all load conditions. This is the best and most economical method of pump speed control.
Variable volume pumping offers the highest saving in pumping energy. However, the capital cost can be slightly higher, depending on the type of variable speed drive used.
The initial cost of variable speed pumping can be reduced by using fixed and variable speed pumps connected in series. On low load only the variable speed pump will operate until it reaches maximum speed. The fixed speed pump will then start to operate and the variable speed pump will reduce to minimum speed.

Variable speed drives

The load duration characteristics of CH require pumping systems to have the flexibility to meet variable flow conditions, which only stepped or variable speed pumping can satisfy.
In most CH applications variable speed control is essential to achieve economy in energy use, effective system control and satisfactory all-year heat supply to consumers.
The most common speed control is the frequency inverter drive, which is now well established for many applications.
The frequency inverter can be designed with a selection switch so that one drive is sufficient for a two pump system, whereby 100% standby pumping is provided.

Frequency inverters

Frequency inverters have high efficiencies over a wide range of speeds, and are particularly suitable for conversion of existing constant speed induction motor systems.
The purchase price is fairly high, but installation costs are minimal because the physical arrangement of the motor need not be altered, as is the case for couplings. Throttling valves in existing systems can be left *in situ* and the frequency inverter installed so that it can be bypassed and the motor run on the mains supply, if the motor size is appropriate to direct on-line or star/delta starting. This provides back-up if the inverter fails.
For larger pumps the extra cost is not significant when compared to that for equipment to limit high starting currents.
The cost of inverter maintenance is negligible. The variable frequency voltage wave-form applied to induction motors to give speed variation is non-sinusoidal, giving rise to high amplitude harmonic currents which necessitate the use of de-rated motors.

Transient pressures

Extensive water transmission and distribution systems are subject to transient pressure surges caused by rapid valve closure, or pump outage. Transient pressures can result in separation of water columns and water hammer causing damage to pipework, expansion absorbing devices, valves and controls. In general, water hammering is likely only for pipes with diameters >500 mm, or if there is a long pipe with no consumer connection (eg the pipe leading from a waste incineration plant).
On completion of the network design a transient pressure network analysis should be

carried out on all networks, and any surge arresters necessary should be included in the pipework system.
Distributed arterial mains pumping and independent load zone pumping can maintain a suitably low steady-state pressure in the system, but there is a possibility that higher pressures will occur in surges resulting from transient fault conditions. Computer simulations of such surges show that in local mains networks serving individual domestic heating systems, the transient pressure is rapidly dissipated by the elasticity of the system. However, surges can cause high pressures to develop along the larger diameter arterial mains. The design of means to minimise the risk of evaporation should be determined by the application of an approved computer package for modelling transient conditions in complex hydraulic networks. This will produce a time-plot of the maximum and minimum pressures occurring at critical positions in the network due to rapid valve closure and pump tripping.
In general, the greatest risk of water hammering will be caused by the incorrect operation of isolation valves, and when pressurising systems fail to maintain the required pressure.

3.10 SYSTEM CONTROL AND MONITORING

3.10.1 General

CHP/CH projects will generally require a centralised control and monitoring (CCM) system to facilitate dependable optimum economic operation of the heat supply system (see figure 12).
The extent and sophistication of the CCM facility will depend upon the policy and operational philosophy of the specific ownership. However, good practice is considered to require a comprehensive investigation of all the operational and safety functions of the system and of the inclusion of a CCM if it enhances the overall economic operation. Basic safety functions must be effected by local direct response equipment not dependent upon any CCM.

3.10.2 Objectives of CCM

The main objectives of a system are to achieve:

- maximum dependability and integrity of the heat supply system
- optimum economic control and operation to meet load and system temperature, mass flow and pressure fluctuations
- minimum manpower requirement.

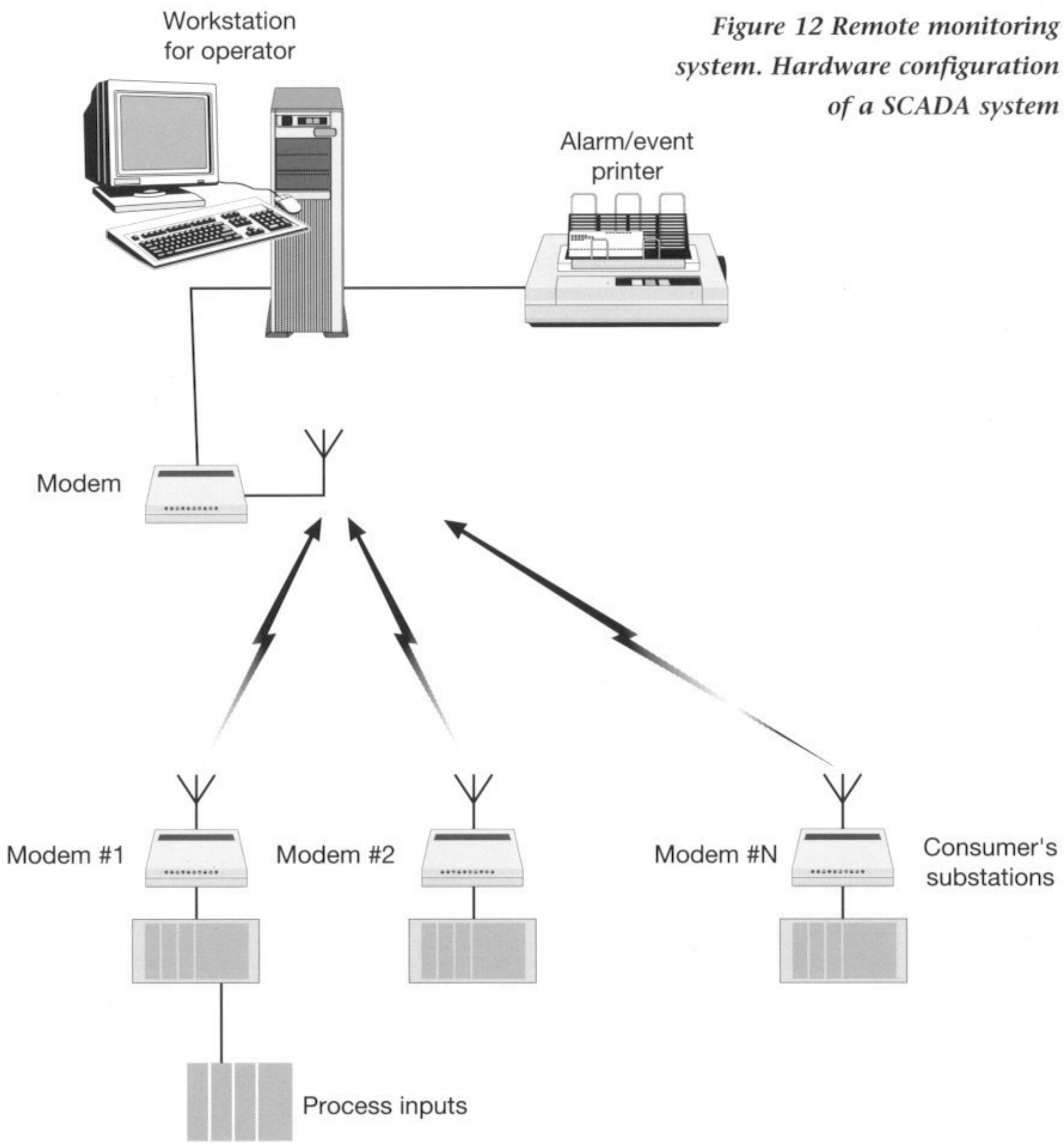


Figure 12 Remote monitoring system. Hardware configuration of a SCADA system

Figure 12 Remote monitoring system. Hardware configuration of a SCADA system

3.10.3 Composition of the CCM system

The CCM generally comprises a main station (MST) often located in the main plant control room. For large projects this is normally manned continuously, and there will be a number of unmanned substations (SSTs), that will be visited regularly.

The main station should consist of a double computer system, incorporating visible field state and alarm displays. Other desirable features are alarm approach indication, a historical database and system parameter graph and/or record generation and maintenance task data recording.

Manual remote control of all system operational controls is essential. Software control program facilities are also generally advantageous.

It is important that the CCM system be built from local controllers that are not dependent

on the computer system. In normal operation the computer will control the local controllers, but if the computer system fails, the CH system can be operated automatically or manually by local controllers.

Certain system conditions should be designated as ‘alarm’ conditions. These should, under all circumstances, be presented to the system controller, eg low temperature, high temperature, high pressure, low pressure, no flow, etc. Alarms should also be conveyed directly, for instance by means of an audible signal, to demand immediate attention, and visible, for immediate identification of the location and extent of the particular alarm condition.

The CCM should include ‘health’ system indication, system state displays, and alarm test facilities to enable rapid evaluation of the system at shift changeover and at times of emergency incident.

Fire and security systems may also be monitored by the CCM, but should operate as stand-alone detection and alarm systems to be included in CHP/CH projects at the discretion of, and according to the requirements of, the owners and insurers.

Underground piping system moisture detection alarms can also be included in any CCM, but this is not so important because moisture develops slowly in insulation, and no rapid action is normally required. In most cases, local fault indicators, giving the status of a moisture detection system, are sufficient.

Data collection relating to the heat consumption of the system and to routine programmes for charging can also usefully be included in the CCM.

3.10.4 CCM substations

The main station should communicate with autonomous computer-controlled SSTs, which are normally unmanned. The SSTs collect and relay information from principal consumers and groups of consumers; and they control, adjust and monitor input and output system conditions of pressure, valve opening, pump speed, temperature, flow, etc.

Software facilities for adjustment loops, fixed condition and sequence controls can be incorporated. Typically SSTs can accommodate 150-400 input/output points. All the functions of the SSTs should be capable of local operation as well as operation from the CCM.

Substations should have electricity supply standby for a suitable period (2-4 hours).

SSTs should be equipped with full routine and emergency working facilities for operating and maintenance staff.

Testing and commissioning the CCM system, or at least the SSTs, before the CH system is commissioned will greatly assist in the testing, commissioning and setting to work of a complex network.

3.10.5 Cable system

Communication between CCM and SSTs is normally by means of direct connection over multi-core armoured or protected control cables.

Care should be taken that any manufacturers’ requirements in respect of screening, core impedance and jointing are satisfied. Generally, underground jointing should be avoided and all terminations should be made on terminal strips that facilitate easy testing and cross-connection when necessary. The cable should contain adequate cores for commons, test requirements and telephonic communication, and spare cores for future expansion and development. Cables should be laid simultaneously with underground mains in ducts, or laid directly in sand with marker tape. When ducts are used they should be laid with draw wires and must be separately defined by marker tape or tiles. Control cables can be laid in common trenches with the heating mains, provided that

clearances necessary to prevent damage by excess temperature or direct mechanical interference are observed.

3.11 DISTRICT COOLING

When evaluating the CH system and trying to identify summer load, there may be potential for district cooling. District cooling is usually based on absorption (ABS) chillers, using CH as the primary heat source. The principal connection of an absorption chiller to a CH system is shown in figure 13. The ABS-chiller comprises five main components: generator, condenser, evaporator, absorber and heat exchanger. The operation of the key components is as follows.

- ***Generator.*** Hot water (from the CH system) is used to boil a solution of a refrigerant (water or lithium bromide) and an absorbent (lithium bromide or water). Refrigerant vapour is released and the absorbent solution is concentrated. Lithium bromide and water are the most common media for absorption cycles.

- ***Condenser.*** The refrigerant vapour released in the generator is drawn into the condenser, and cooling water cools and condenses the refrigerant.

- ***Evaporator.*** Liquid refrigerant flows through an orifice into the evaporator. Due to the lower pressure in the evaporator, flashing takes place. The flashing cools the remaining liquid refrigerant down to the saturation temperature of the refrigerant at the pressure present within the evaporator (approximately 4°C for a lithium bromide/water chiller). Heat is transferred from the chilled water to the refrigerant, thereby cooling the chilled water and vaporising the refrigerant.

- ***Absorber.*** Refrigerant vapour from the evaporator is drawn into the absorber section by the low pressure resulting from the absorption of the refrigerant vapour. It returns to the liquid state in the absorption process. The diluted solution is circulated back to the generator (concentrator).

- ***Heat exchanger.*** The heat exchanger transfers heat from the relatively warm concentrated solution being returned from the concentrator to the absorber and the dilute solution being transferred back to the generator. Transferring heat between the solutions reduces the amount of heat that has to be added in the concentrator and reduces the amount of heat that has to be rejected in the absorber.

The cooling water required in the absorber and the condenser is generated in an auxiliary cooling fan or tower.
The ABS-chiller is very reliable because it has no other moving parts other than a few pumps. Most of the operating cost comes from the wasted heat in the cooling fan/tower. When the ABS-chiller is designed to be connected to a CH scheme, it improves the viability of the scheme. This is because it increases the summer load, which normally consists of DHW consumption only.
It is important to notice that the higher the design flow temperature used, the smaller the investment cost of the ABS-chiller, especially when planning an ABS-chiller using CH as the driving heat source. Against this is the increased heat loss in the whole CH distribution system (mainly in the network), and loss of power production in CHP mode. Modern ABS-chillers can operate at temperatures of 90-120°C. The lower the temperature, the larger and more expensive the unit will be. The selection of the correct

temperature level requires optimisation and viability calculations.

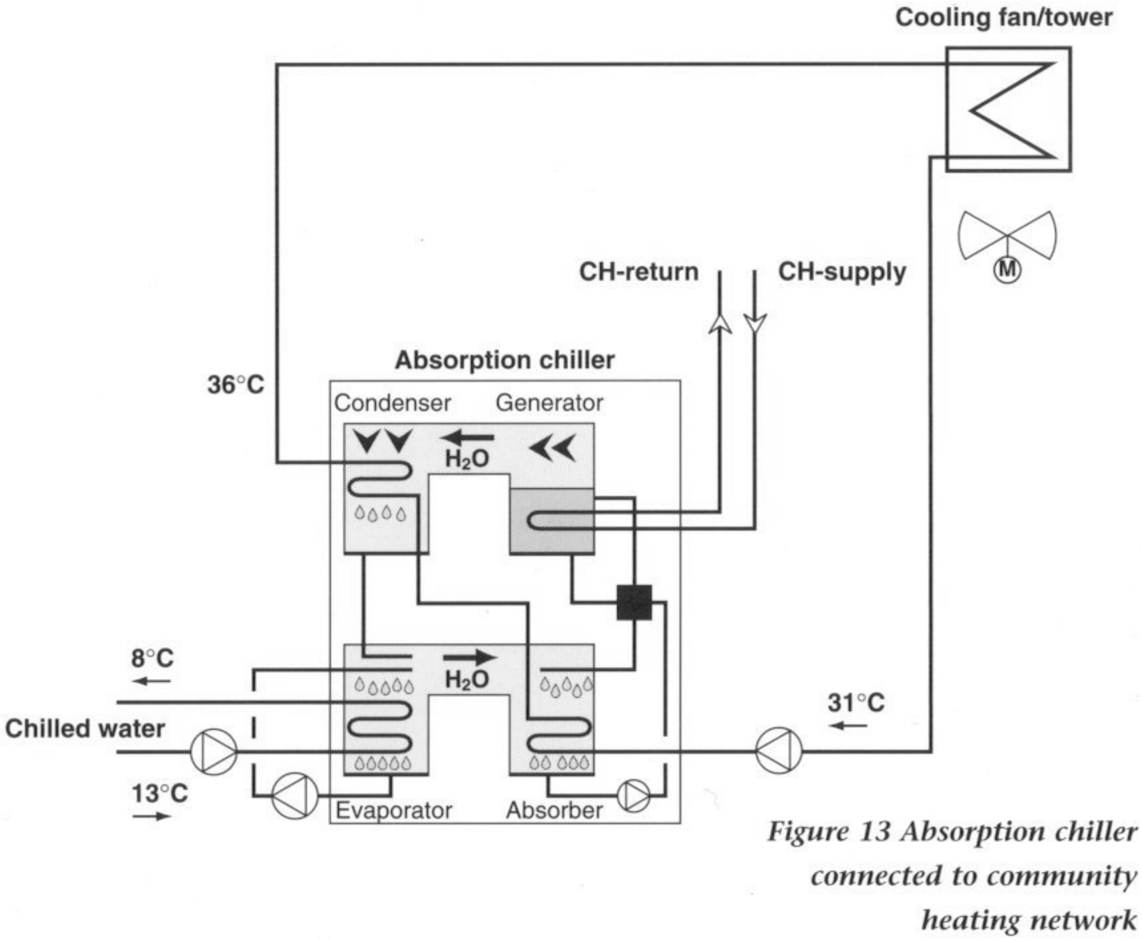


Figure 13 Absorption chiller connected to community heating network

OPERATION AND MAINTENANCE 4

4.1 INTRODUCTION

The success of any CHP/CH scheme depends upon sustained continuity of operation at maximum levels of output, thereby developing customer confidence in the supply of energy, and maximising revenue from sales of energy.

It is imperative that operation and maintenance issues are fully and effectively addressed as part of the design procedures. Higher initial costs will be recouped with considerable interest, ensuring long-term viability. Systems configured solely by financial constraints, to the exclusion of fulfilling engineering requirements, inevitably incur increasing maintenance and operational costs, suffer poor reliability, and customer confidence is lost, threatening the future of the scheme.

Design procedures should incorporate extensive consultation with operators who have experience of similar schemes. Drawing on such experience will help to prevent flaws in the initial design.

4.2 PLANNED PREVENTIVE MAINTENANCE (PPM)

Once the design and equipment to be installed has been approved, work should begin immediately on preparing the maintenance schedules for the scheme. It is important at this stage to set up the scheme so that information is readily available and complete in the form of equipment lists, drawings, and manufacturers' literature. A computerised PPM scheme should be set up, using either 'off the shelf' software, or created using a database package. For a CHP/CH scheme, it is advisable to invest in a package comprising a plant record system with a maintenance feature; this eliminates data duplication and provides financial information.

Creating an inventory of all the plant is fundamental to the operation and maintenance of the scheme. Each item should be given a unique identification (ID) number, with which it should be clearly marked. The plant inventory will cover the physical characteristics of plant such as size, type and location, and will be an integral part of any PPM scheme. If the ID number itself indicates features of the items of plant, great care should be taken in deciding how the numbers are to be generated, so that future additions, modifications, and removals do not lead to difficulties.

When an item of plant is entered into the inventory the maintenance requirements for that item can also be included. The most usual source of this information is manufacturers' literature, which will specify the maintenance requirements, the required frequency, and often details the equipment that will be needed to carry out the tasks. This information will be used to generate worksheets covering maintenance needs on a daily, weekly or monthly basis.

Having collected the data it will then be necessary to schedule the work throughout the year, taking into account the fluctuation in demand on the CHP scheme. Daily, weekly and annual cyclic fluctuations will probably be evident, and operational experience will assist the choice of appropriate scheduling of maintenance work. In order to ensure the schedule is adhered to, the PPM system should record when the job was done. The system should be used to produce lists of outstanding work as well as providing schedules for the coming maintenance period.

PPM schemes should be able to store historical information on plant items; this will help when considering repetitive defects and malfunctions, and when amending maintenance schedules.

The PPM system will be useful when determining the level of spares to be carried in order to conduct the recommended maintenance. From this a maintenance budget can be built up.

The PPM system can provide vital information on the skills level required of staff, and any associated need for a training programme, which can then be implemented prior to the scheme being operated. The areas of prime importance are:

- boiler/CHP plant
- electrical generation equipment
- distribution mains
- valve pits and chambers
- secondary distribution substations
- domestic and commercial control equipment
- pumping equipment

- instrumentation
- electrical equipment.

Once the maintenance requirements have been established, a plan for their implementation needs to be drawn up. This will include whether the maintenance should be carried out using in-house staff, or partly in conjunction with the specialist contractors who will be called in to service the plant according to the manufacturers' recommendations. Above all, it is of vital importance that maintenance schedules are adhered to and historical data are gathered from day one of operation.

4.3. OPERATIONAL PROCEDURES

To operate any CHP scheme safely, and to its maximum efficiency, it is of vital importance that clear operational parameters are defined. These parameters will be determined from the initial design data and will vary greatly, depending on the size and complexity of the scheme. All available design data should be collated to produce an operational procedure manual that will form a sound basis for efficient operation.

All the crucial parameters affecting efficiency should be trend-monitored; there should be regular reviews so that operational procedures can be adjusted to ensure maximum efficiency is maintained, and costs reduced.

Areas of operation which need to be constantly monitored are:

- fuel consumption
- boiler efficiency
- CHP efficiency
- electrical consumption
- raw water usage
- distribution pumping pressures and volumes
- flow and return temperatures
- process chemical usage
- equipment lost time analysis
- spares replacement costs
- water quality (physical and chemical).

Weekly performance figures or graphs can be produced from monitored data. There should be a brief weekly meeting to examine the data, and to try to identify any unfavourable trends. Corrective action can then be taken at an early stage before efficiency is undermined.

4.4. SURVEILLANCE SYSTEM FOR MOISTURE DETECTION IN PRE-INSULATED PIPE SYSTEMS

4.4.1 General

As a general rule, all pre-insulated pipe systems should have a surveillance system installed to detect moisture in the foam insulation. These systems use wires running through the insulation to detect moisture entering either from outside the pipe, due to the ingress of ground water, or from leaking service pipes. The surveillance system should monitor the complete pipe system continuously, using automatic detection units to ensure rapid indication of potential problems due to moisture.

4.4.2 Installation and maintenance

The surveillance system must be installed exactly in accordance with the manufacturer's specifications and instructions, and the following must be provided to the installer before installation takes place:

- circuit diagrams and the planned location of components
- installation instructions from the system supplier.

The correct operation of the system depends on proper installation and testing, and these should be supervised at all stages.
It is essential that any parts of the surveillance system installed above ground are inspected at regular intervals of six months or less, and that the operation of the automatic detection units is verified as part of an operational programme for the complete pipe system.
On small systems of less than 100 m of installed pipe length the use of portable detection units or impulse reflectometers is acceptable, but caution is advised because skilled operation and interpretation, not normally available to the site operating personnel, is required. These units are NOT adequate for use on larger systems.

4.4.3 Other standards and references

There are four BS EN Standards (see section 5.2) for the manufacture of pre-insulated pipes and associated components, and a draft is in preparation for surveillance (monitoring) systems.
The EuHP Handbook for the design, installation and maintenance of pre-insulated pipe systems has further details on surveillance systems (see section 5.2).

4.5. WATER TREATMENT

4.5.1 General

The purpose of water treatment is to maintain the availability and efficiency of the CH circuit in the most cost-effective way. Treatment will ensure that maximum heat output is available at all times, and that the design life of each component in the network is reached with a minimum of maintenance requirements.
CH system water, which receives heat either indirectly by means of a heat exchanger from a primary source (such as a steam turbine), or directly from a boiler, is heated to a maximum temperature not exceeding 120^{o}C (MTHW).
This water then circulates through the network and, in order to deliver heat to a customer, it flows through the primary circuit of a heat exchanger. In some cases the

water circulating through the secondary side of the heat exchanger is the domestic/commercial hot water supply. The chemical quality of the CH water must therefore be safe for domestic hot water use in case leakage occurs within the heat exchanger. Substances harmful or toxic to humans or animals, or which may be put to any subsequent commercial use, should not be used within the CH system water.
The quality of raw and mains supply water varies throughout the UK. Any water considered for use in a heat transfer and conveying system must be analysed to establish the water treatment requirements. Water from a borehole or surface source will require filtration before treatment. Water treatment must be considered at the feasibility stage, and as part of the design, installation and maintenance of the system.
Factors affecting the secondary water system adversely are:

- scaling of the heating surfaces due to thermal decomposition of (temporary) alkaline hardness in the water
- corrosion of the materials used in the construction of the circuit due to:
  - — acidic conditions in the water
  - — dissolved oxygen in the water
  - — bacterial decomposition of minerals in the water, forming ammonia (aggressive to copper and its alloys) and sulphides (aggressive to copper and its alloys and mild steel)
- excessive gas formation in radiators and the high points of the system due to:
  - — bacterial decomposition of minerals in the water, forming nitrogen and hydrogen sulphide
  - — acidic conditions in the water, forming hydrogen
- blocking of waterways, instruments, controls, meters, and fouling of magnetic heat sensors and primary heat exchangers due to sludge and scale formed by:
  - — dissolved oxygen corrosion of the mild steel materials in the circuit
  - — acidic corrosion of the mild steel materials in the circuit
  - — sulphide corrosion of the mild steel materials in the circuit
  - — hardness scale formed by the thermal decomposition of temporary alkaline hardness in the water.

4.5.2 Controlling water quality

4.5.2.1 Base-exchange

The required treatment depends on the hardness of the water source, and the material composition and operating regime of the system.

- *Hard water.* Base-exchange reduces hardness to a satisfactory level. When accompanied by proper treatment and dosing, this will generally prevent internal corrosion of the internal pipe surfaces of the system.
- *Soft water.* While not requiring base exchange, soft water may require special filtration and pretreatment to provide internal pipe surface protection against corrosion.

The heat exchanger supplying heat to the CH water is effectively a low-temperature boiler. The guide for the general principles of water treatment is British Standard 2486, 1978 ‘Recommendations for Treatment of Water for Land Boilers’, with some exceptions:

- hydrazine should not be used because of its toxicity
- the treatment chemicals are generally harmless when diluted, so leakage in

either the primary/secondary or the secondary/tertiary heat exchangers should present no major problem

- because of serious scale-forming potential in the primary and secondary systems, silicate treatments should not be used.

4.5.2.2 Initial fill

The CH system should first be tested and then flushed. The initial fill should comprise base-exchange softened mains water. This should have a hardness of approximately 2 mg/l with other mains water minerals present, ensuring there is sufficient buffer capacity against pH change. Expensive demineralised water fails in this respect.
As this water is circulated, sodium sulphite solution — an oxygen scavenger — should be added until analysis of samples from the circuit shows a sulphite residual of 30 mg/l as Na_2S0_3. This concentration will reduce as the temperature is raised and reaction with dissolved oxygen takes place; further sodium sulphite should be added to achieve the desired residual concentration. With continued circulation, alkali in the form of sodium hydroxide or sodium carbonate solution should be added to raise the pH to between 8.9 and 9.5. To prevent microbial fouling in the system caused by sulphate-reducing bacteria, an initial charge of biocide should be added while the water is circulating. Care should be taken in the selection of a suitable chemical, bearing in mind the possible contamination of the DHW. Specialist advice should be sought to ensure that an effective biocide is used without the possibility of harmful physiological effects.

4.5.2.3 Regular operation

The make-up water to the circuit, replacing operational water losses, should be pre-treated by passage through a base-exchange softening plant, producing water with a total hardness not greater than 2mg/l as $CaCO_3$. The capacity of the softener and any soft water storage should be designed to allow for large quantity make-up after partial drainage for maintenance or other water losses due to blow-down for quality control. The water quality must match the requirements of the quality of steel used in different components within the system.
The circulating water and the make-up water should be sampled and analysed regularly, the sampling frequency being determined by the rate of change of chemical concentrations, degree of make-up and the extent of contamination noted from the analysis reports. Daily analyses may be necessary during the early life of the system, but weekly or monthly analyses may be sufficient once an operating regime has been established. The chemical analysis targets* for the CH water circuit are as follows.

Total hardness as mg/l $CaCo_3$	5 maximum (note 1)
pH	9.5-10 (note 2)
Residual sulphite as mg/l Na_2SO_3	15-30 (note 3)
Alkalinity to pH as mg/l $CaCO_3$	Present (note 4)
Alkalinity to pH 4.4 as mg/l $CaCO_3$	100-400 (note 5)
Chloride as mg/l NaCl	100 maximum (note 6)

Ammonia as mg/l NH_3	7 maximum (note 7)
Electrical conductivity maximum (microsiemens/cm) at 25ºC	2000 (note 8)
Suspended solids	20-40 mg/l
Oil/grease	10-20 mg/l
Copper	0.02 mg/l
Iron	0.02 mg/l
Zinc	Zero
Manganese	0.03 mg/l (note 9)
Total bacterial count - cells/ml	10-2 - 10-3 (note 10)
Sulphate-reducing bacteria	none
Filamentous bacteria	10 cells/ml

Additionally, the circulating water should be oxygen-free, oil-free and sludge-free.
*The target specification is a best-balance condition: soft water with a pH well above acidity level to avoid in-system softening, which causes deposition and fouling.
Note 1. Below this concentration, the deposition of scale on the heating surfaces of the heat exchangers will be negligible. Every effort should be made to keep the total hardness in the make-up water at a minimum, preferably below 2 mg/l $CaCO_3$. Should contamination of the CH water circuit take place resulting in an increase in the hardness level above 5 mg/l, the circuit water should ideally be blown-down, the make-up being good quality softened water. If blow-down is not practicable — because of the large quantities of water involved — the hardness may be lowered by adding an orthophosphate. If the bulk of the excess hardness is present as soluble calcium salt, the phosphate added will react with the hardness to form insoluble calcium phosphate. The selection of the phosphate will depend on the prevailing pH of the heating water circuit. If the pH is:

- normal – disodium monohydrogen orthophosphate, which is neutral in solution, should be used. For complete reaction 1 kg of $CaCO_3$ requires 0.95 kg of anhydrous disodium monohydrogen orthophosphate.
- high – monosodium dihydrogen orthophosphate, which is acid in solution, should be used. For complete reaction 1 kg of $CaCO_3$ would require 0.80 kg of anhydrous monosodium dihydrogen orthophosphate.
- low – trisodium orthophosphate, which is alkaline in solution, should be used. For complete reaction 1 kg of $CaCO_3$ would require 1.09 kg of anhydrous trisodium orthophosphate.

This type of phosphate treatment should not be used as a routine practice instead of external water softening because the reaction product, mainly calcium phosphate, will deposit on the heating surfaces of the primary/secondary heat exchanger and act as a barrier to heat transfer.
Note 2. Within this range, corrosion of the copper/brass/bronze/mild steel components in the system will be minimal. Zinc and aluminium will become electrically anodic and will corrode, dissolving into solution; they should not be used in the circuit. Soluble

aluminium may also have long-term physiological effects if ingested in the event of leakage in the domestic hot water heat exchangers.
Note 3. Sodium sulphite reacts with dissolved oxygen in the circulating water, preventing oxygen corrosion of the mild steel parts of the system. The main source of dissolved oxygen is the make-up water. Water leakage should therefore be kept to a minimum, in order to reduce the need for a high level of sulphite addition to the circuit.
Note 4. This alkalinity should be adjusted to maintain the pH within the target range. Its concentration will normally be approximately 10% of the total alkalinity level.
Note 5. This ‘total’ alkalinity will reach equilibrium when the required pH range is reached.
Note 6. Excessive chloride ions are potentially corrosive. Base-exchange softeners use strong sodium chloride solutions. Malfunction of this type of softener may contaminate the treated water with chloride ions. Any significant increase in chloride ions within the circulating water should therefore trigger investigation of the softener operation.
Note 7. Since the ammonia is a consequence of bacterial activity, an increase in ammonia over a period of time indicates the need for biocide addition.
Note 8. The electrical conductivity is a measure of the dissolved solids in the water. Its variation indicates intentional or accidental chemical or water addition to the circulating water. Too high a figure can promote corrosion.
Note 9. Soluble manganese at a concentration greater than 0.03 mg/l may initiate pitting corrosion of copper. The soluble manganese is unlikely to be derived from the heating circuit, but may be present in some naturally occurring waters. The soluble manganese concentration should be checked in the initial fill water charge and in supplies for make-up. Excess levels of manganese can be corrected in the initial fill by dilution with demineralised water.
Note 10. Avoidance of dead water pockets, and using circulation water with pH 9.0 and temperature above 70^{o}C to all parts of the system inhibits bacterial growth.

4.5.2.4 Alternative water treatment systems Demineralised water

Demineralisation removes as many soluble materials as possible – not only are the hardness salts removed but also the majority of all other minerals and metallic ions contained in the water. Demineralised water is of much higher quality than softened water. The cost of demineralisation plants for CH is generally prohibitive; however, if one is available for prime plant purposes, it may be economic to use demineralised water for the CH system.

Reversed osmosis system

Osmosis is the process by which solvent transfer through a semi-permeable membrane from a dilute to a concentrated solution. For any two solutions there is a maximum differential pressure which can exist across the membrane. This is called the ‘osmotic pressure’. If, however, a greater pressure than normal osmotic pressure is applied to the concentrated solution, the flow will be reversed, transferring the solute from the concentrated solution to the dilute solution.
When the osmosis principle is applied to the purification of water, the plant will reduce the dissolved mineral salt content to approximately 5%-10% of its initial value while not passing bacteria and pathogens. The process uses higher pressure to separate the raw water into two streams – a pure water stream and a concentrated stream that carries the dissolved mineral salts away from the membrane.
Pretreatment by acid-dosing or base-exchange is usually required before applying reversed osmosis. In general, the base-exchange process is sufficient for CH applications.

4.5.2.5 Removal of suspended matter

Black suspended matter within the circuit may be caused by bacterial activity. This matter generally has a small particle size and is therefore difficult to remove by filtration. However, it can be prevented with biocide treatment. Another possible cause of suspended matter is magnetite (Fe_3O_4), a corrosion product formed in systems with high temperature and pressure. This is magnetic, so it should be removed by magnetic filtration – such particles (size 1 to 5 microns) are very abrasive and readily damage stainless steel heat exchangers, and pump seals. The presence of magnetite also disturbs heat meter readings.

Should further action become necessary, partial filtration, bypassing about 5%-10% of the circulating water volume through a filter, is practicable and will, over a period, remove a large proportion of the suspended matter. Full flow fine filtration is not a practical proposition, because the flow restriction would be too severe. Even for full flow coarse filtration, which is recommended, it is important to optimise the filter coarseness – much energy can be saved by choosing filters with favourable flow and differential pressure characteristics.

Various types of filter are available to prevent blockage in pre-treatment processes and heat distribution systems. In selecting an appropriate unit, account has to be taken of the concentration, size and nature of the solids to be removed, the standard of treatment to be attained and the expected maintenance period and life of the filter element. Periodic examination of the particulate from filters should enable any exceptional bacterial growth to be identified and specialist advice sought on additional treatment.

Sidestream filtration units developed for CH schemes combine a fabric filter with a magnetic filter; the latter helps trap particles of magnetite. Initially the bag filter may need to be coarse but it can be gradually replaced by a finer fabric down to 5 microns. Although sidestream filters will not remove bacteria, larger colonies of bacteria that have come loose (often referred to as ‘slime’) will be filtered out. Part-stream filters, which should be built into the system from the beginning, help by removing suspended solids which often act as a source of nourishment to bacteria.

4.5.3 Financial aspects of chemical water treatment

The financial return on physical and chemical treatment is difficult to quantify, because the treatment is of a preventive nature – prevention of corrosion of the system and the prevention of the deposition of scale in the heat exchangers. Scale deposit acts as a barrier to heat transfer, lowering the efficiency of the system and leading ultimately to a complete blockage of the heat exchanger. The outage cost of such a heat exchanger at a critical CH load period, during severe winter weather for example, would not only be costly but would seriously affect heat availability unless expensive stand-by equipment had been installed. Corrosion of the buried heat mains pipework would have major financial implications.

4.5.4 Community heating system design considerations

Careful design and operation can mitigate future problems.

- Dead legs in pipework should be avoided because they encourage the growth of bacteria and act as a source of contamination to the rest of the system.

- Plant should not, if possible, be fabricated from mixed metals, although certain combinations are now accepted, eg mild steel and copper and its alloys.

- Inadequate flow velocities will lead to deposition of suspended solids and other

particulate matter. This will lead to the formation of differential aeration and concentration cell effects, and hence to corrosion.

Brasses used in heating systems should be specified to BS 2871: part 2 and BS 699 to avoid dezincification. Dezincification of brasses occurs when chloride ions and bicarbonates are present in certain ratios, with pH of about 8.3. When the pH is below this value dezincification will not occur in the cold, but is still liable to occur at heating system temperatures.
High flow velocities will keep suspended solids and particulates mobile and reduce the tendency for the build-up of silt or sludge on the surface of equipment. However, it can lead to breakaway of corrosion products, thus increasing the solids content of the water. Erosion of bends and fittings is likely to be caused by mobile particulates rather than the water velocities typically used for economic pipework design. Copper bends and fittings should be restricted to pipework zones having a flow velocity of less than about 1.5 m/s.
If the meters used depend on electrical conductivity, or have magnetic coupling, the manufacturer should be consulted in case there are specific water condition requirements.
Leaking flanges and open make-up storage tanks increase the susceptibility of the system to ingress of oxygen, and hence the risk of corrosion. Provided primary water is properly treated, direct heating systems are inherently protected from internal corrosion. Excessive water loss and failure to treat the system make-up water adequately can cause extensive corrosion in consumers' heating systems. Secondary circuits in indirect systems should also be monitored for water condition.
A full and careful visual inspection and cleaning will be required before commissioning new installations. Old plant being incorporated in the system will need to be examined. Tuberculation nodules and heavy deposits indicate poor water quality and corrosion. Bacteriological examination should be carried out to determine the extent of contamination and species present. Where hydro-testing is required, the water quality for the test should be specified.
A treated make-up water storage capacity of 2%-3% of the system volume (equivalent to one week's normal loss) can be taken as a useful guide.
Vulnerable parts of the system can be protected against freezing by pumping, trace heating and insulation; not by the use of anti-freeze additives.
Planned preventive maintenance (PPM) programmes, including the monitoring of water quality, recording of results and corrective water, are essential.
Treatment chemicals may be added by means of a hand pump, as required, but on large schemes where there is continuous monitoring of make-up water, an automatic dosing pump adjusted to suit the make-up rate will result in a closer control of system quality. Automatic continuous monitoring of pH is also available which can give an early warning if the system is going out of condition.

REFERENCES, CURRENT STANDARDS AND CODES OF PRACTICE5

The following documents comprise the principal sources of information used in the compilation of this Guide, or are of use in the application of this Guide. All references are identified by general subject.

5.1 HEAT METERS

New European standard:

EN 1434-1 Heat meters – general requirements

EN 1434-2 Heat meters – constructional requirements

EN 1434-3 Heat meters – data exchange and interfaces

EN 1434-4 Heat meters – pattern approval tests

EN 1434-5 Heat meters – initial verification tests

EN 1434-6 Heat meters – installation, commissioning, etc.

The above EN 1434 has been published in the UK as BS EN 1434 and supersedes BS 7234.

Council Directive 93/76/EEC Article 3

5.2 PRE-INSULATED PIPE SYSTEMS

European Standards:

EN 253 Pre-insulated bonded pipe systems for underground hot water networks

EN 448 Pre-insulated fitting assemblies

EN 489 Pre-insulated steel valve assembly Joint assembly for pre-insulated district heating pipes

European District Heating Pipe

Manufacturers Association, District Heating Handbook, by Peter Randløv, 1997.

5.3 HEAT EXCHANGERS

CEN ENV 1148 Heat Exchangers – Water to Water

Heat Exchangers for District

Heating – Test Procedures for

Establishing the Performance Data

5.4 HOUSING REFURBISHMENT

British Standards Institute:

BS 8211, part 1: British Standard Code of Practice on the Energy Efficient Refurbishment of Housing Applications Manual to accompany B5821 1 part 1 'Energy Efficient Refurbishment of Housing' British Standards Institution
389 Chiswick High Road, London W4 4AL
AMA:

Too hot to handle (1988)
AMA, 35 Great Smith St, London SW1P 3BJ

5.5 INTERNATIONAL ENERGY AGENCY PUBLICATIONS

Programme of Research, Development and Demonstration on District Heating

Annexe I: Publications

1986: R9	Small-scale Combined Heat and Power Plants
1986: R10	Cost Analysis of Community Heating Networks
1987: R4	Temperature levels in District and Local Heating Systems in Sweden
1987: R6	Technical and Economic Assessment of New Distribution Technology
1988: R12	Small Heat Meters
1988: R13	State-of-the-Art Review of Coal Combusters for Small Community Heating Plants
1988: R16	Summary of Research Activities 1983-1987

Annexe II: Publications

1989: R1	District Heating and Cooling R & D Project Review	90-72130-07-3
1989: R2	Advanced District Heating Production Technologies	90-9002876-5
1989: R3	Static Problems in the Laying of Plastic Jacket Pipes	90-72130-09-X
1989: R4	Fittings in Plastic Jacket Pipelines	90-72130-08-1
1990: R5	Welded Sleeve Techniques for Plastic Jacket Pipes	90 72130-17-0
1990: R6	New Methods in Underground Engineering and Installing of District Heating Pipelines	90-72130-16-2
1990: R7	A Technology Assessment of Potential Telemetry Technologies for District Heating	90-72130-10-3
1990: R8	Guidelines for converting building heating systems for hot water district heating	90-72130-12-X
1990: R9	Advanced Energy Transmission Fluids Final	90-72130-11-1
1990: R10	Heat Meters - Report of research activities – Annexe II	90-72130-15-5
1990: R11	Thermal Energy from Refuse Analysis Computer Program	90-72130-18-9
1990: R12	Summary of research activities 1987-1990	90-72130-19-7

Annexe III: Publications

Reports:

1992: P1	The environmental benefits of District Heating and Cooling	90-72130-36-7
1992: P1.1	DETECT Consequence model for Assessing the environmental benefits of District Heating and Cooling in a well defined area	
1992: P2	CFC-Free Plastic Jacket Pipes	90-72130-28-6
1992: P3	District Heating piping with plastic medium pipes able to withstand high transverse loadings	90-72130-29-4
1992: P4	Bends for Plastic Jacket Pipe Systems, able to withstand high transverse loadings	90-72130-30-8
1992: P5	Consumer Heating System Simulation	90-72130-32-4
1992: P6	R & D Project Review	90-72130-33-2
1993: P7	Advanced Energy Transmission Fluids Final Report	

of Research, Annex III 90-72130-
34-0
1993: P7.1 Design and Operation of Ice Slurry Based District
Cooling Systems 90-72130-
50-2
1993: P8 Supervision of District Heating Networks 90-72130-
35-9
1993: P9 Promotion Manual for District Energy Systems 90-72130-
39-1

Brochure:

A Clean Solution? It is also your responsibility.

Annexe IV Publications

1996: N1 Integrating District Cooling with Combined Heat and Power 90-72130-
87-1
1996: N2 Advanced Energy Transmission Fluids for
District Heating and Cooling
90-72130-
94-4
1996: N3.1 Guideline to Planning and Building of District
Heating Networks 90-72130-
84-7
1996: N3.2 Bend-Pipes 90-72130-
83-9
1996: N3.3 Execution of Connections to Pipelines in Operation 90-72130-
82-0
1996: N4 Quantitative Heat Loss Determination by Means
of Infrared Thermography - the TX Model 90-72130-
95-2
1996: N5 Efficient Substations and Installations 90-72130-
88-X
1996: N6 Temperature Variations in Preinsulated DH Pipes
Low Cycle Fatigue
90-72130-
97-9
1996: N7 Managing a Hydraulic System in District Heating 90-72130-
86-3
1996: N8 A Review of European and North American Water
Treatment Practices
90-72130-
93-6
1997: N9 Summary of Research Activities 1993-1996 90-5748-
001-8

5.6 OTHER REFERENCES

CHPA

Community Heating: UK Action Plan by Gill Owen. CHPA, 1992.
World Energy Council

District Heating/Combined Heat & Power. World Energy Council, 1991.

Danish District Heating Association

Water Treatment in Danish Community Heating Systems. Danish District Heating Association, June 1995.

Association of Electricity Producers

Electricity production connected to the local network: a guide, October 1996. Association of Electricity Producers (0171 930 9390).

'District Energy Schemes Coming in from the Cold' by Dennis Jenkin. Gas Matters, 1997. EconoMatters Ltd.

Building Services Research and Information Association

'Permissible Temperature of Heating Equipment' Technical Note TN 476, by NS Billington. BSRIA. June 1976.

Chartered Institution of Building Services Engineers

CIBSE guide Book B. CIBSE 1986

Dansk Standards

DS 2178, DS 2179, D52180, D52181 and DS 2182
Dansk Standard Association service in pipes for district heating

British Standards Institute

BS EN ISO 9000: Quality management and quality assurance standards

BS EN 834:	1995: Heat cost allocators for the determination of the consumption of room heating radiators. Appliances with electrical energy supply
BS EN 835:	1995: Heat cost allocators for the determination of the consumption of room heating radiators. Appliances without an electrical energy supply, based on the evaporation principle
BS 699	1984 (1990): Specification for copper direct cylinders for domestic purposes
BS 1387:	1985 (1990): Specification for screwed and socketed steel tubes and tubulars and for plain end steel tubes suitable for welding or for screwing to BS 21 pipe threads
BS 1710:	1984 (1991): Specification for identification of pipelines and services
BS 1965:	Specification for butt-welding pipe fittings for pressure purposes 1963 (1983) Part 1: Carbon steel
BS 2486:	1997: Recommendations for treatment of water for steam boilers and water heaters
BS 2871:	Specification for copper and copper alloy tubes Part 2: 1972: Tubes for general purposes Part 3: 1972 Tubes for heat exchangers
BS 2972:	1989: Methods of test for inorganic thermal insulating materials
BS 3958:	Thermal insulating materials Part 1: 1982: Magnesia preformed insulation Part 2: 1982: Calcium silicate preformed insulation Part 3: 1985: Metal mesh faced man-made mineral fibre mattresses Part 4: 1982: Bonded preformed man-made mineral fibre pipe sections Part 5: 1986: Specification for bonded man-made mineral fibre slabs Part 6: 1972 (1980) Finishing materials: hard setting composition, self-setting cement and gypsum plaster

BS 4164: 1987: Specification for coal-tar-based hot-applied coating materials for protecting iron and steel, including a suitable primer

BS 4508: Thermally insulated underground pipelines
Part 1: 1986: Specification for steel cased systems with air gap
Part 4: 1977: Specification testing and inspection requirements for cased systems without air gap

BS 8207: 1985 (1995): Code of Practice for Energy Efficiency in Buildings

OIML

Regulation International Recommendation No. 75 - Heat Meters. OIML, 1994

Chartered Institution of Building Services Englneers

CIBSE Commissioning Code Series W - Water Distribution Systems. CIBSE, 1994

Combined Heat and Power Association

Guidance for the Preparation of Technical Specifications for Small Scale (<1 MW_e) Combined Heat and Power (CHP) Installations. CHPA, 1996

5.7 DETR PUBLICATIONS

The following DETR publications are available from BRECSU and ETSU. (See back page for contact details.)

Energy Services for the Public Sector. An Executive Summary

Energy Services for the Public Sector. A Working Guide

Good Practice Guides

1 Guidance notes for the implementation of small scale packaged combined heat and power
3 Introduction to small scale combined heat and power
43 Introduction to large scale combined heat and power
82 Energy efficiency in housing – guidance for local authorities
115 An environmental guide to small-scale combined heat and power
116 Environmental aspects of large-scale combined heat and power
165 Financial aspects of energy management in buildings
176 Small-scale combined heat and power for buildings
226 The operation and maintenance of small-scale CHP
240 Community heating – a guide for housing professionals

There is also a CIBSE Application Manual on CHP in Buildings in preparation.

Good Practice Case Studies

67 Energy efficient refurbishment of high rise housing. York House, Bradford
68 Energy efficient refurbishment of high rise housing. Stannington Estate, Sheffield
80 Rejuvenation of community heating – pipework refurbishment in Manchester
81 Community heating in Sheffield
82 Consumer connection to community heating in Sheffield
312 Community heating in Nottingham: an overview of a rejuvenated system
313 Community heating in Nottingham: domestic refurbishment
314 Community heating in Nottingham: pipework refurbishment
370 The use of combined heat and power in community heating schemes — four case studies

General Information Reports

23 The IEA programme on district heating and cooling
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APPENDIX 1 LEGISLATIVE FRAMEWORK

A1.1 LOCAL AUTHORITY CAPITAL CONTROLS

The Private Finance Initiative (PFI) (see section 2.6.3) provides an opportunity for local authorities to enter into partnership projects with the private sector without reducing their capital spending power under the current central government regime for controlling local government expenditure. There may also be central government revenue support to assist with the ongoing revenue costs of PFI schemes. Generally, however, current central government controls require capital expenditure to be financed in one or more of the following ways:

- by borrowing – provided the authority's Basic Credit Approval issued by central government is not exceeded.
- by capital grants and contributions from third parties including European grants, such as the European Regional Development Fund (ERDF)
- by the use of capital receipts – the proceeds from the sale of capital assets can be used to finance capital expenditure after a percentage specified by central government has been set aside to replace existing debt
- by revenue contributions – the impact on rent levels and the level of council tax, together with the authority's overall capping limit, will determine the extent to which revenue contributions can be used in any year to finance capital expenditure.

A1.2 EU PROCUREMENT RULES

A1.2.1 Introduction

The EU procurement rules are contained in the Treaty of Rome and EU Directives relating to public sector works, supplies and services contracts (general sector procurement) and to contracts awarded in the water, energy, transport and telecommunications sectors for works, supplies and services (utilities procurement).

A1.2.2 General principles

The general principles behind the procurement rules are the prohibition of discrimination against nationals of, and the freedom to provide goods and services throughout, other member states and the need for transparency in selecting tenderers and awarding

contracts. Each directive sets a qualifying value threshold for contracts above which contracts are to be advertised by specific procedures. The directives distinguish between open (ie including no pre-qualification), restricted (ie including pre-qualification) and negotiated procedures. Under the directives, tender notices and award notices must be published in the Official Journal of the European Union (Official Journal) in a prescribed form, and the directives impose time limits for publication and responses. The directives set out the criteria on which tenders should be awarded, namely selection on the basis of the lowest price or the most economically advantageous tender. Contracting authorities (normally government departments, agencies and state-funded bodies) and contracting utilities must be aware of the procedures and requirements of the regulations when tendering for and awarding any contracts that exceed the value thresholds.

A1.2.3 General sector procurement

A1.2.3.1 Works contracts

The EU Directive (93/37/EEC) is implemented in the main by the Public Works Contracts Regulations 1991 (SI 1991:2680). The basic qualifying threshold is currently set at special drawing rights* (SDR) S million (£4 016 744). The rules apply principally to building and civil engineering works together with associated activities such as installation work. Public work concessions are subject to a more relaxed regime under the rules.

* Following the adoption of Council Directive *97/52/EC* on 13 October 1997, amending the EU public sector directives to align with the new Government Procurement Agreement (GPA), all thresholds for the public sector should now be expressed in SDR.

Where the value of the contract exceeds the threshold, contracting bodies are required to publish a prior information notice giving the essential characteristics of qualifying works contracts following decisions to approve the planning of works. A contract notice should be published in the Official Journal when offers are sought in relation to a works contract. When inviting tenders, negotiated procedures may be used only in exceptional circumstances. The choice is mainly between open and restricted procedures under which all tenderers must bid against the same specification and terms and conditions of contract. The negotiated procedure allows a preferred bidder to be chosen before the final terms of the contract are agreed. There are strict provisions on technical standards requiring the use of European standards in tender documentation in preference to national ones.

The award of the contract must be either on the basis of the lowest price or the most economically advantageous tender. If this latter test is used a contracting authority should specify which further elements would be relevant, such as technical merit, delivery dates, after-sales services, running costs etc, when possible in order of importance. Unsuccessful bidders can obtain reasons for rejection of their tender so the contracting authority must maintain compliance records. After the award of the contract, new or additional work can only be carried out in certain very limited circumstances.

A1.2.3.2 Supplies

The EU Directive (93/36/EEC) is implemented by the Public Supply Contracts Regulations 1995 (SI 1995:201). The supply rules apply where a contracting authority seeks to purchase or hire certain goods. The qualifying threshold is currently SDR 200 000 (£160 760).

Again, negotiated procedures are the exception. As with the works rules, a contracting authority will usually employ the open or restricted procedures. There are requirements to publish a prior information notice above 750 000 ECU (£584 901) for contracts of the

same product and a contract notice in order to attract offers.
The comments in section A1.2.3.1 above on award criteria, technical specifications and maintaining records of awards also apply to the supply rules.

A1.2.3.3 Services

The EU Directive is implemented by the Public Services Contracts Regulations 1993 (SI 1993:3228). Services are defined in the rules by exclusion – they do not include contracts of employment or service, works (under the works rules), certain utilities-related services or services concessions. The value threshold is set at SDR 200 000 (£160 760).
As per the works and supply rules, provisions are made for prior information notices above 750 000 ECU (£584 901) for contracts falling to the same category of services specified in Part A of Schedule 1 to the Services Regulations above, contact notices, use of the open, restricted or negotiated procedures, award criteria and use of technical specifications. A distinction is made between Category A services (eg maintenance and repair of vehicles and equipment, accounting, architectural services, property management services) which are subject to the full tendering procedures and Category B services (eg legal, education and vocational, recreational, cultural and sporting services) which are subject to limited tendering procedure requirements.

A1.2.4 Utilities

EU Directive 93/38 deals with works, supplies and services in respect of utilities. The Directive has been implemented in the UK by the Utilities Contracts Regulations 1996 (SI 1996: 2911). The Regulations list classes of bodies identified as utilities. The rules also list specified activities (such as the supply of gas or electricity). If an entity falls under the former list and is engaged in an activity under the latter list, then the utilities rules will apply.
The thresholds are ECU 5 million (£3 899 337) in the case of works contracts and ECU 400 000 (£311 947) for supplies and services in the energy, water, and transport sectors and ECU 600 000 (£467 920) for supplies and services in the telecommunications sector.
The main difference between the utilities directives and the general sectors directives is the more flexible procedure that can be used in the former case. Again, there is a choice between the use of the restricted, negotiated and open procedures and time limits/procedures are set out. The rules on award criteria, standards and record keeping are similar to those for the general sector. The specific procurement rules to be applied to a CHP project will depend on the precise characteristics of each project. However, it is likely that most CHP projects, if caught by the procurement regime, will fall within the scope of the utilities regulations (assuming the relevant thresholds are met).

A1.2.5 Enforcement

Any contractor or potential contractor that can prove that it has been prejudiced by the failure to apply the procurement rules correctly will have a cause of action against the contracting authority or utility in national courts. Under the UK implementation of the enforcement directives (there is a general remedies directive and a more particular utilities remedies directive) it is not, however, possible to set aside a contract once it has finally been entered into. In such a case the only remedy would be damages.

A1.3 ENVIRONMENTAL ISSUES

A1.3.1 Integrated pollution control and local authority air pollution

control

A CHP plant requires an integrated pollution control (IPC) authorisation where the plant is carrying out a prescribed process within Part A of Schedule 1 of The Environmental Protection (Prescribed Processes and Substances) Regulations 1991, as amended. IPC involves the control of emissions to air, water and land so as to minimise effects in all three media, thus delivering the Best Practicable Environment Option (BPEO) overall. Discharges to the public sewer still require the consent of the sewerage undertaker. IPC authorisations do not always cover all emissions from, or activities on, a site so other forms of regulation may apply alongside them.
IPC authorisations are granted and regulated by the Environment Agency (for England and Wales), the Scottish Environmental Protection Agency or the Environment and Heritage Service (for Northern Ireland). Guidance for individual Environment Agency inspectors is contained in IPG Guidance Note S25.01 on waste incineration and energy from waste plants for the following wastes – chemical; clinical; municipal; sewage sludge; animal carcasses and drum residues.
If the process being operated is a process prescribed within Part B of Schedule 1 of the Environmental Protection (Proscribed Processes and Substances) Regulations then the process is subject to authorisation and regulation by the relevant local authority under the Local Air Pollution Control (LAPC) regime. This regime covers only emissions to air and therefore separate authorisations may be required in respect of waste and water. Statutory guidance to local authorities on particular processes is contained in various Secretary of States' Process Guidance Notes, including, though not limited to, PGI/10 and PGs 5/1 and 3. A full list of guidance notes is available from Air and Environmental Quality (AEQ) division in DETR or on the internet at address http://www.aeat.co.uk/netcen/airqual/info/labrief.html. Depending on the thermal input of a CHP plant and/or the type of fuel being burned, the plant may fall within either IPC or LAPC.

A1.3.2 Planning

To construct and operate a CHP plant, planning approval is generally required. An environmental statement prepared under The Town and Country Planning (Assessment of Environmental Effects) Regulations 1988 as amended or The Electricity and Pipeline Works (Assessment of Environmental Effects) Regulations 1990 will often have to accompany the planning application.
The planning and pollution control systems are essentially independent but complementary. In general, planning authorities need not be consulted in determining applications for authorisations. Planning permission is not a prerequisite for IPC or LAPC authorisation, although planning permission or an established use certificate is required for the grant of a waste management licence. The Environment Agency must be consulted in relation to environmental impact assessments of some projects and may have input on some planning issues.
Conditions of planning permissions and IPC or LAPC authorisations may conflict. This may necessitate a reapplication for planning permission for a site design meeting the requirements of the authorisation. It may therefore be advantageous to approach both the planning authority and the Environmental Agency or local authority environmental health department at an early stage, thereby encouraging early consultation between them.
Planning Policy Guidance Note No. 23 'Planning and Pollution Control' (PPG 23) issued by the Department of the Environment (now the Department of the Environment, Transport and the Regions (DETR)) provides guidance on the relationship between

planning and pollution control legislation. The systems are complementary but separate. The planning system controls development and land use while pollution control concerns the processes carried on and substances produced. PPG 23 states that planning authorities should not duplicate controls, which are the responsibility of other bodies. There is a specific chapter in PPG 23, which addresses planning applications for waste management facilities. Within the chapter there are a number of paragraphs relating to incinerators. However these paragraphs do no more than set out the factors that the planning authority should take into account. PPG 23 is currently subject to amendments and a consultation draft for an amended PPG 23 regarding waste is now available. The draft deals with incineration and the relevant planning considerations in greater detail, even citing CHP schemes as a potential benefit for certain urban locations.
It is advisable to read PPG 23 in conjunction with the relevant IPC or LAPC guidance notes discussed above.

A1.3.3 Waste

A waste management licence is not required where waste is recovered or disposed of as part of processes covered by an IPC authorisation. If waste is being handled and the activity is not covered by an IPC authorisation a waste management licence may be required. This may be the case where waste feeding an incinerator is sorted to extract any valuable material or non-combustible material.
Regardless of any IPC authorisation, all controlled waste will be subject to the requirements of the duty of care for controlled waste requiring monitoring of waste movements by a system of transfer notes and providing written description of the waste; the waste should also be kept safely and securely.

A1.3.4 Water

Discharges to public sewers must normally be covered by a trade effluent discharge consent issued by the relevant sewerage undertaker or a trade effluent agreement with the sewerage undertaker. Where an IPC authorisation applies covering discharge of prescribed substances, a trade effluent discharge consent is still required and it will cover matters such as volume, temperature, composition and the charge made by the sewerage undertaker.
Discharges of water to controlled waters from a CHP plant, which is subject to an IPC authorisation, do not require a separate consent. Discharges to controlled waters not covered by the authorisation, or if no authorisation is in place, would require consent from the Environment Agency.
Where any pollution of controlled waters occurs, or is likely to occur, the Environment Agency may carry out remedial works and recover the costs or may under new provisions (yet to enter into force) serve a works notice requiring the polluter to carry out remedial works itself. If any water or liquid waste is treated on site prior to discharge and an IPC authorisation does not cover the facility it is DETR's view that the effluent treatment plant does not require a waste management licence as long as the subsequent discharge is regulated under the water legislation.

A1.3.5 Contaminated land

Provisions contained in Part IIA of the Environmental Protection Act 1990 (inserted by section 57 of the Environment Act 1995), which are not as yet implemented, will introduce a new definition and specific regime for the control of contaminated land. The legislation will make the polluter liable and will, if the polluter cannot be found, impose liability on the owner or occupier. Generally, local authorities will be the relevant regulatory bodies under the contaminated land regime, however, for 'special sites' the

Environment Agency will be responsible. Where land is contaminated and an IPC authorisation is in place in respect of processes being carried out on that land, a remediation notice will not be served in respect of the contamination where it appears to the enforcing authority that the Environment Agency may exercise its powers under the IPC system to remedy the harm and recover the costs. The contaminated land regime will not apply to contamination resulting from activities in respect of which a waste management licence is in force, whether breaching the licence or not.

A1.3.6 Clean air

Discharges to the air will mainly be controlled by the Environmental Protection Act 1990 LAPC regime or regulations under the Clean Air Act 1993, and generally enforced by local authorities.

Operators of certain types of combustion processes, prescribed in Regulations under the 1990 Act, will need to obtain an authorisation from the local authority which limits and controls various air pollutants harmful to health emitted by those processes. For example, operators of appliances between 0.4 and 3 MW net rated thermal input burning fuel manufactured from solid waste or appliances incinerating general waste under 1 tonne per hour, would be authorised in accordance with Guidance Notes.

Dark smoke (defined by the Act) from chimneys serving furnaces of fixed boilers or industrial plant, or from trade premises on open land, is limited by Regulations under the 1993 legislation (a consolidation of earlier Acts), as are amounts of grit dust and fumes from non-domestic furnaces (domestic furnaces generally have a maximum heating capacity less than 16.12 kilowatts). Local authorities also need to approve the height of chimneys serving such plants.

Many urban local authorities have designated smoke control areas, usually covering domestic properties, in which it is an offence for any smoke to be emitted from a chimney. In these areas only authorised fuels (smokeless fuels) may be used, unless burnt on specific appliances exempted from the controls by Regulations.

A1.3.7 Statutory nuisance

Emissions from a plant, such as noise, smoke, smells and dust may also constitute a statutory nuisance in respect of which the local authority may serve an abatement notice. Individuals may also seek imposition of an abatement order in the magistrate's court. A Local Authority requires consent of the Secretary of State to prosecute for non-compliance of an abatement notice in respect of certain statutory nuisances if proceedings might be taken under the IPC or LAPC regime.

A1.3.8 Planning consent

Planning permission is required for carrying out the development of any land (s57 (1) Town and Country Planning Act 1990).

'Development' is the 'carrying out of building, engineering, mining or other operations in, on, over or under land or the making of any material change in the use of any buildings or other land' (s55 (1), Town and Country Planning Act 1990).

A1.3.9 New generating development

If the CHP/CH system is to be built as a new entity or as part of a new generating development then it will require the carrying out of various operations. *Prima facie,* planning permission under the Town and Country Planning Act will be required for these operations, unless otherwise authorised in accordance with the provisions of the Electricity Act 1989.

A1.3.10 Additions to existing generating development

If the CHP/CH system is installed as an addition to an existing generator, then planning permission will be required only if there is a material change. This is a question of fact and degree. A mere 'intensification' of a use is not material unless it occurs to such a degree that it amounts to a material change in the character of the use. The fluctuation or variation of the use ancillary to a primary use are not material changes, unless the use intensifies to such an extent that it becomes a co-primary use or supplants the primary use.

If the provision of the CHP/CH system amounts to 'development', planning permission may be deemed to be granted under the Town and Country Planning (General Permitted Development) Order 1995 in respect of some of the works if the developer is a statutory undertaker (which includes a licence holder under Section 6(1) of the Electricity Act 1989).

A1.3.11 Other associated legislation

The Electricity Act 1989 s36 provides that the consent of the Secretary of State for Trade and Industry is required for the construction of an electricity generating station with a capacity exceeding 50 MW. Upon granting consent the Secretary of State is entitled to direct that planning permission for the development and for any ancillary development should be deemed to be granted (s90 (2) of the Town and Country Planning Act 1990).

A1.4 OPENING THE PUBLIC HIGHWAY A1.4.1 The New Roads and Street Works Act 1991

It is an offence for a person other than the street authority, which means, in the case of a maintainable highway, the local highway authority, and in the case of a private street the street managers, to break up or open a street for the purpose of placing, inspecting, maintaining, adjusting, repairing, altering or renewing apparatus otherwise than in pursuance of a statutory right or a street works licence (s51 (1)).

However, the street authority may grant a street works licence permitting the placing or retention of apparatus in the street, and thereafter to maintain etc the apparatus, and to execute any works required for or incidental to such works (including, in particular, breaking up or opening the street).

A1.4.2 The Electricity Act 1989

The provider of the CHP/CH system may also derive its powers from the Electricity Act 1989. S.6 (1) allows the Secretary of State to grant a licence authorising any person to generate electricity for the purpose of giving a supply to any premises or enabling a supply to be so given.

Such a licence may provide that any reference to any purpose connected to the carrying on of the activities which the licence holder is authorised by his licence to carry on include a reference to any purpose connected with the supply to any premises of heat produced in association with electricity, and any reference to electric lines or electrical plant included a reference to pipes and associated works used or intended to be used for conveying heat (s10 (3)).

A licence holder may install under, over, in, on, along or across any street and from time to time inspect, maintain, adjust, repair, alter, replace or remove any electric lines or electrical plant; and any structures for housing or covering any such lines or plan; and any works requisite for or incidental to the purposes of the works including opening or breaking up any street.

However, except in cases of emergency arising from faults in any electric lines or electrical plant, a street which is not a maintainable highway shall not be opened or broken up except with the consent of the street authority or consent of the Secretary of State.

A1.5 RELATIONSHIP WITH ELECTRICITY REGULATIONS

A1.5.1 General background

There is a detailed regulatory code for the production of electricity. The major piece of legislation is the Electricity Act 1989. This permits the Government to provide for more detailed legislation through statutory instruments.

The Electricity Act 1989 distinguishes, in relation to electricity, between the act of generation and the act of supply. The *prima facie* rule in relation to both generation and supply is that they are prohibited unless the person is exempt or licensed.

Licences are granted by the Secretary of State for Trade and Industry or by the Director General of Electricity Supply (DGES) pursuant to section 6, Electricity Act 1989.

A generator or a supplier must obtain a licence, unless it is exempted from the requirement to do so under a statutory instrument known as 'The Electricity (Class Exemptions from the Requirement for a Licence) (No. 2) Order 1995'. The exemptions contained in that document are limited. For a generator they exclude those who:

(i) do not at any time export from their site more than 10 MW; or

(ii) do not at any time export from their site more than 50 MW if the declared net capacity of the generating station is less than 100 MW; or

(iii) generate offshore.

For a supplier the exemptions include those who:

(i) supply power not exceeding at any time 500 kW; or

(ii) re-sell electricity which is supplied to them by the holder of a supply licence; or

(iii) supply electricity which they have generated themselves for their own use, or for supply to a single customer or a qualifying group of customers on the same geographical site as the generating plant; or

(iv) supply electricity offshore, which has been generated offshore.

A 'qualifying group' of on-site customers broadly comprises companies that are part of the same group or certain joint ventures that are located on the same physical site as the generator.

On 31 March 1998, a new licence exemptions order came into force, The Electricity (Class Exemptions from the Requirement for a Licence) Order 1997. This order has the effect of deregulating the supply licence exemptions regime for on site supply in particular. Generating licence exemptions are unchanged from the 1995 Order.

Transitional exemptions from the requirement for a licence came to an end on 31 March 1998, as shown in the 1995 Order.

The liberalisation of the licence exemptions regime is aimed at boosting competition and promoting efficient local generation and delivery of electricity to industrial, commercial, and domestic customers in local communities.

The new opportunities for exempt suppliers will arise from the ability to supply up to 100

MW to any customer (of which up to 1 MW may be supplied to domestic customers) on the same site as the generating station, or off-site if the supply is made over private wires. This is in addition to the supply exemptions in the 1995 Order, which will continue. As a result, suppliers will continue to be able to make unlimited exempt supply on site to a single customer or a qualifying group, plus the additional 100 MW on the same site or over private wires to any customer. Supply of up to 1 MW to domestic customers within the overall limit of 100 MW will be subject to a maximum price which is set in the Order. The maximum price will provide some protection for domestic customers of exempt suppliers. In addition, the Electricity Association is developing a voluntary Code of Practice for exempt suppliers, and is taking forward this work in close consultation with other interested parties. The Code will be administered by the Association of Energy Suppliers (AES) and compliance with the code will be mandatory on licence-exempt suppliers subscribing to the AES as code members. Although the code will not be legally binding, it will be publicised and will set the standards by which licence-exempt suppliers to the domestic market will be judged.

A1.5.2 Implications of being licensed

As indicated above, licences are obtained from the DGES or the SOS and generally follow the same or a similar format and their contents are therefore generally predictable. Their major implications are:

(I) licence-holders must pay an application fee and an annual fee to the DGES;

(ii) licence-holders are required to join the Pool (the wholesale market in electricity);

(iii) each supplier is required to contribute to the Non-Fossil Fuel Levy administered by OFFER; and

(iv) each generator is obliged to comply with the Grid Code and the relevant Distribution Codes, which govern the operation of the high and lower voltage transmission and distribution systems.

A1.5.3 Implications of joining the Pool

The basic implication of joining the Pool is that (with some exceptions) all electricity must be sold by generators to the Pool, for which each generator will receive the Pool Purchase Price, ie the price determined by the computerised bidding system for all generators. All suppliers must also purchase their requirements of electricity from the Pool at a different (usually higher) price – Pool Selling Price. It is higher than the Pool Purchase Price since it incorporates ‘uplift’ which covers certain costs, including the costs of system stability and security – stable voltage and frequency (sometimes known as ancillary services) and transmission losses.

A generator will always be required to sell to the Pool unless it can also supply its power to consumers at its site or on the same ‘Trading Site’, in which event it will sell to the Pool and buy back its electricity at Pool Purchase Price (if a net exporter) and, if a net importer, pay Pool Selling Price only on the difference.

Trading site

A centrally dispatched generator (ie one that exceeds 100 MW) must apply for Trading Site status in order to sell ‘net’. The generator may apply to have its power station treated as a Trading Site under the Pooling and Settlement Agreement (PSA). The application will be successful provided the power station conforms to one of the specified electrical diagrams and the applicant satisfies the other set conditions.

Pool fees

Energy Settlements and Information Services Limited (ESIS), which administers the Pool, is able to provide written estimates on receipt of an estimate request form containing details of proposed supply and generation operations. ESIS also organise presentations lasting about three or four hours for people interested in joining the Pool. It may take up to a month for ESIS to provide a full-fledged estimate of Pool membership costs.

Energy Pool Funds Administration Limited

Energy Pool Funds Administration Limited operates the banking side of the Pool and fees are payable to it as well. These are based on the total annual cost of operating Pool banking arrangements, which is currently approximately £1 500 000. This charge is split evenly between generators and suppliers and then allocated on a points system according, broadly, to megawatt hours generated or supplied.

Use of system and connection agreements

A licensed generator will be required to enter into a connection agreement with either the local PES or, if connected to the NGC Supergrid, with The National Grid Company plc (NGC). A use of system agreement will also be necessary with NGC and/or the local PES.

NGC charges for use of its system by a zonal charging system which is intended to reflect the costs to NGC of installing, operating and maintaining transmission system assets to the standards prescribed by its transmission licence.

NGC also charges for connection assets at the connection point.

Each of NGC and the local PES are obliged to offer terms for connection pursuant to their licences. Enquiries should be made of the local PES to establish the time delay in making a connection to the extent there is not already a connection.

A1.6 OBLIGATIONS TO CUSTOMERS/CUSTOMER CHARTER

Individual supply agreements will regulate the relationship between customers and the CHP company. This might be supplemented by a customer charter, which is discussed in section 2.2.3 of this Guide. Experience shows that it is also helpful to set up a ‘Consumers’ Committee’ comprising representatives of local community groups, the ward councillors from the local authority and representatives from the CHP company and from any other body providing services associated with the scheme. Terms of reference might be along the following lines.

The Consumers’ Committee shall serve in an advisory capacity and shall be a means of:

(a) exchanging views and information on matters of mutual interest affecting consumers of district heating

(b) dealing with complaints and other matters which are not settled satisfactorily through the usual channels

(c) making recommendations on such matters to the appropriate body.

For issues where the services of ‘an honest broker’ would be helpful the appointment of a scheme ombudsman might be considered.

APPENDIX 2 ENVIRONMENTAL ASSESSMENTS

A2.1 INTRODUCTION

The principal difference in environmental impact between heating premises individually and communally (CH) arises from the use, for the latter, of CHP. Combining heat and power generation can lead to a significant reduction of the use of primary energy sources per unit of energy consumed by the final user. Widespread use of CHP in the UK would have the effect of reducing the total national emissions of combustion products emitted to the atmosphere. However, it is possible that the conversion of existing plant, or construction of new facilities, may increase local levels of air pollutants. This appendix will discuss:

- the main pollutants that are likely to be an issue in typical CHP installations
- the responses that have been taken at national and international levels to control the emission of these pollutants
- the steps that must be taken to reassure planning and other authorities that the project will meet the required standards
- a method of calculating the savings in emissions that are likely to result.

A2.2 ENVIRONMENTAL CONCERNS

Defining exactly what issues amount to concerns for our environment is often subjective and frequently fraught with scientific uncertainty. In addition, concerns may be relevant at a local, regional or global level and in the long, medium or short term. Particular concerns may have more than one effect, on more than one medium. In this section we are primarily concerned with emissions to air, but other possible environmental effects will be described.

A2.2.1 Atmospheric concerns

There are many pollutants emitted to the atmosphere that cause concern, as illustrated in table A2.1. Processes that utilise the combustion of fossil fuels such as coal, oil or natural gas rely on the energy released when carbon (C) and hydrogen (H) in the fuel are combined with atmospheric oxygen (O_2). This reaction produces carbon dioxide (CO_2) and water (H_2O) in varying quantities, depending on the chemical composition of the fuel. However, the presence of other elements in the fuel and air, and the type of combustion process, lead to the production of other gases that may be considered pollutants. For example, sulphur in the fuel leads to the creation of sulphur dioxide (SO_2), and nitrogen in the air produces various oxides of nitrogen (NO_x).

Table A2.1 Example of concerns relating to the atmosphere

Concern	Causes
URBAN AIR POLLUTION by oxides of nitrogen, ozone and fine particulate matter	Burning fossil fuels (eg power stations, motor vehicles and industrial processes)

WIDE-SCALE POLLUTION resulting from long-range transport of photochemical oxidants and acidic compounds causing damage to forests and sensitive aquatic environments	Burning fossil fuels (eg power stations, motor vehicles and industrial processes)
GLOBAL CLIMATIC CHANGE due to release of carbon dioxide and other greenhouse gases leading to impacts on climate, sea level and world agriculture	Burning fossil fuels (eg power stations, motor vehicles and industrial processes)
OZONE LAYER DEPLETION following the release of fluorocarbons and other halogenated alkanes leading to increased levels of ultraviolet radiation reaching the Earth's surface.	Release of refrigeration working fluids, use of chlorinated carbons and other chemicals as solvents in industrial processes and as fire extinguishers.
TOXIC POLLUTANTS (eg cadmium, benzene, asbestos, and dioxins) may be ingested by humans through air, food and drinking water, leading to health deterioration	Routinely and accidentally released by industrial processes, motor vehicles
POLLUTION OF INTERNAL ENVIRONMENTS in homes and workplaces causing health impacts	Routinely and accidentally released, and the unpredictable behaviour of some synthetic materials

A2.2.1.1 Carbon dioxide

The primary result of the combustion of carbon fuels, carbon dioxide (CO_2) is an inert gas in the atmosphere, which forms part of the natural carbon cycle of the earth. The combustion of increasing quantities of fossil fuels is generally thought to be contributing to a global increase in the levels of this gas in the atmosphere. This increase has been linked to the greenhouse effect, with its inherent risk of global warming and subsequent climatic instability.

A2.2.1.2 Sulphur dioxide

Sulphur is present in widely varying quantities in all fossil fuels, depending largely on the circumstances in which these fuels were created. When the carbon element of a fuel is burnt, the sulphur also reacts with atmospheric oxygen to create sulphur dioxide. When released into the atmosphere this may be involved in many complex reactions leading to dry or wet deposition of acidic compounds (eg 'acid rain') that can be a hazard to health, damage the ecological environment, and erosion of cultural heritage of buildings, etc.

A2.2.1.3 Oxides of nitrogen

Nitric oxide (NO) and nitrogen dioxide (NO_2) are formed at combustion from two sources – the reaction between atmospheric oxygen and atmospheric nitrogen in the high temperature of the combustion chamber, and the reaction with atmospheric oxygen with nitrogen present in the fuel. While the latter reaction is a function of the fuel utilised, the former is present in all combustion processes. NO_2 is considered harmful to respiratory systems. NO reacts with atmospheric ozone to deplete this radiation-shielding gas in the upper atmosphere, and helps to cause smog at ground level. In addition, NO reacts with water vapour, forming nitric acid, which contributes to acidic depositions.

A2.2.1.4 Carbon monoxide

Carbon monoxide is produced if the combustion of a carbon fuel is not complete. This may occur due to complex factors in the combustion process, especially poor control,

and emission rates are usually very low compared to the carbon dioxide emission. Carbon monoxide is a very toxic gas that may have serious health implications at low doses, and contributes to reactions that form urban photochemical smog.

A2.2.1.5 Particulates

Commonly, these very small particles are unburnt carbon or ash entrained in emission gases. While many may settle near to their point of emission, the smaller ones can often be transported over long distances. The size range of these particles may be very large, but there are often significant quantities of very small particles that can be inhaled deeply into human and animal lungs, causing permanent respiratory damage. In addition these particles may also contain carcinogenic compounds.

A2.2.2 Other concerns

There are many other factors that may cause concern in the planning and operation of CHP schemes. However, these are often case-specific and require careful examination at an early stage in the project planning process. Table A2.2 illustrates some examples.

Table A2.2 Examples of other concerns

Concern	Causes
NOISE from industrial processes and transport systems associated with manufacturing sites, causing nuisance and health concerns	Inadequate screening of noisy processes (may also be affecting the workforce adversely)
ODOURS from industrial process emissions and waste storage and disposal facilities causing nuisance	Leaks and the poor design of facilities. Inadequate control of furnace operation
VISUAL IMPACT of industrial sites, transport systems associated activities (eg mining). Reduction of visibility due to emissions to atmosphere. Damage to the amenity value of forests, natural and agricultural landscapes following the effects of pollution emissions	Poor site and process planning; inadequate site management procedures; lack of sufficient state planning control and foresight
LAND USE for industrial, commercial and residential purposes decreases agricultural productivity and damages habitats.	Development on 'green-field sites', plus associated infrastructure

A2.3 RESPONSES

Public concern and scientific evidence persuaded policy-makers and law-makers to act at an early stage to consider environmental protection in the national interest. In a recent survey, over 90 % of respondents in the UK considered that protection of the environment was a problem. This section will review the level of this concern and discuss the responses of government on three levels – local, national and international. Appendix 1 of this Guide, to which reference should be made, describes the specific nature of the legislative response in more detail.

A2.3.1 International conventions

A2.3.1.1 Climate change

To tackle the threat of increasing world climate change 153 countries signed the United Nations Framework Convention on Climate Change at Rio, which came into force in March 1993. Under the Convention, developed countries, including the UK, agreed to take measures aimed at returning emissions of greenhouse gases to 1990 levels by the year 2000. In 1994 the UK was the first country to publish plans as to how this may be achieved.

In December 1997 the Kyoto Protocol secured international agreement. This Protocol sets a legally binding target of an average reduction of 5.2% for industrialised countries in the levels of the six greenhouse gases between 2008 and 2012, compared to 1990. The UK government has agreed to reduce emissions to 12.5% below 1990 levels over the period 2008-2012. The government issued (October 1998) a consultation paper 'UK Climate Change Programme', designed to stimulate a national debate on how the UK can meet its targets.

The science of climate change is addressed by the Intergovernmental Panel on Climate Change (IPCC), established in 1988, which reports on scientific progress in understanding the issues involved.

A2.3.1.2 Sulphur dioxide

The United Nations Economic Commission for Europe (UNECE) Second Sulphur Protocol has set reduction targets for SO_2 emissions at 50% reduction by 2000, 70% by 2005 and 80% by 2010, from a 1980 baseline. By the end of 1994 the UK had cut emissions by 45%, due mainly to the closure of coal-fired plant.

A2.3.2 The background to pollution control in the UK

Recent changes in society's attitudes to environmental protection and the influence of EU legislation have been reflected in a gradual shift in the law from centring on the protection of private and individual rights to focus more on general environmental protection. In addition, there is growing concern about global and transfrontier problems, the control of hazardous waste, minimisation of waste, the conservation of natural resources and the protection of ecosystems. The International Energy Agency, whose focus spans all energy conservation and energy efficient technologies, typifies this concern.

A2.3.2.1 Common characteristics of pollution control

Despite the breadth of legislation, most of the elements of pollution control have the following characteristics in common.

- The potential polluter must apply for consent from an authority charged with controlling the process that gives rise to potential environmental concerns.
- The potential polluter will have to use the best available techniques not entailing excessive cost (or in some cases the best practicable means) to avoid pollution.
- The potential polluter must pay fees to accompany the application for consent, in order to support the authority's supervisory work in accordance with the 'polluter pays' principle.
- The authority has the power to take enforcement action to prevent breaches of pollution control.

- The authority has the power to require the polluter or the site owner to abate any harm being caused to the environment, and in some cases may take remedial action itself.
- The plant operator has rights of appeal against the authority concerned.
- Public registers are maintained, and publicity surrounding the authorisation procedure leads to public scrutiny of the control policy.
- Criminal sanctions (including large fines and/or prison sentences) are possible for those operators failing to comply with the appropriate control policy.
- There are remedies for those affected by nuisance or pollution – often based in common law rather than legislation.

A2.3.2.2 Agencies of control

Department of the Environment, Transport and the Regions (DETR)

The DETR has overall responsibility for supervision of the legislation. The Department publishes the Regulations under which the particular controls are administered, guidance notes and advice circulars on the handling of applications. Appeals may be made to the Secretary of State for the Environment Transport and the Regions, and the Secretary may judge those applications that raise potentially contentious issues.

The Environment Agency

The UK Environment Agency, created in the Environment Act, 1995, took over the functions of Her Majesty's Inspectorate of Pollution (HMIP), the National Rivers Authority (NRA) and the waste regulation functions of local authorities, in April 1996. The agency, and its equivalent in Scotland and Northern Ireland, is a unified authority for environmental protection and enhancement. It is responsible for monitoring environmental conditions and gives advice to government on standards. It regulates emissions to air, water and land to achieve the standards set, and is responsible for enforcing those standards.

Local authorities

Local authorities' duties cover the implementation of planning legislation, including, for the most significant new developments, the process of environmental assessment. Control of air emissions from less polluting processes is also covered by the new system of Local Air Pollution Control (LAPC) developed in the Environmental Protection Act (EPA), and under the Clean Air Acts (which cover smoke emissions).

The Health and Safety Executive (HSE)

The HSE is the main body responsible for the enforcement of the legislation designed to protect work forces from danger. A Memorandum of Understanding exists between the HSE and the Environment Agency to coordinate those issues where overlap exists with respect to Integrated Pollution Control.

European Environment Agency

This body is charged with gathering information about the state of the environment in the member states of the EU, including its quality, sensitivity and pressures upon it. However, its functions will be reconsidered periodically, with a view to their extension into other areas, for example monitoring the effectiveness of implementation of EU legislation.

A2.3.3 The impact of EU membership

The EU has a strong commitment to environmental protection in its policy structure. There are a number of ways in which this influences CHP developments. The Large Combustion Plant Directive of 1988 requires member states to implement actions to reduce emissions of NO_x and SO_2. Although CHP and all gas turbine plants were specifically excluded from the provisions, the growth in gas-powered generation capacity is likely to result in legislation being passed soon. The EU has also introduced directives that limit the concentrations of NO_2 and SO_2 found in ambient air at ground level.

Table A2.3 Determination and implications of pollution control regime

Does the plant…	Then it must…
have a combustor fuel burning capacity, that exceeds 50 MW?	be a process termed a 'Part A process'. This will be covered by an Integrated Pollution Control (IPC) authorisation issued by the Environment Agency (see A2.3.4.1).
have any individual item of equipment that has a fuel-burning capacity that could exceed 20 MW?	be a process termed a 'Part B process'. This will be covered by Local Air Pollution Control.
burn any fuel?	be authorised under the Clean Air Act 1993 by the Local Authority to set the chimney height.

A2.3.4 UK legislation

The Environmental Protection Act 1990 (EPA) is the main body of law relating to controlling atmospheric emissions in the UK. This Act consolidated many of the previous measures, and incorporates ways to allow the adoption of legislation to meet EU requirements. The EPA is structured in such a way as to differentiate between the different scale of projects. The following checklist will identify which level of provisions applies for the proposed project.

A2.3.4.1 Integrated Pollution Control (IPC)

IPC aims to:

- apply the best available techniques not entailing excessive cost to minimise the release of pollutants and to render harmless any that are released
- consider discharges to air, water and land in the context of attempting to minimise the impact of the process on the environment as a whole
- monitor and enforce compliance with statutory requirements.

IPC is administered by the Environment Agency (for England and Wales), the Scottish Environmental Protection Agency or the Environment and Heritage Service (for Northern Ireland). Involves issuing and revising an authorisation every four years, or when major changes are made to the process. This authorisation is drawn up after reference to guidance notes (section A1.3.1), issued for all processes covered by IPC, and a record of correspondence. The application, and the authorisation, is placed on public record.

A2.3.4.2 Local Air Pollution Control (LAPC)

Guidance notes on best practice have been issued to the environmental health department of local authorities, which include factors that must be taken into account before authorisation is issued. Local authorities also control the regulations on chimney height and are responsible for the planning aspects of project development. This topic will be covered in more detail in the next section.

A2.3.5 Future developments

The objectives and structure of pollution control regimes are expected to remain the same for the foreseeable future. However, continued downward pressure on acceptable ground-level pollutant concentrations can be expected, especially in light of the failure of measures already taken, eg catalytic converters on motor vehicles, to deliver acceptable environmental conditions. The effect of international agreements is likely to be small, because the UK has already embarked upon a programme of removing coal-burning capacity and replacing it with gas-powered generation.

A2.4 PROJECT DESIGN AND CONSTRUCTION

This section will outline the steps that must be considered in relation to the wider environment when bringing a project to commissioning.

A2.4.1 Planning permission

Planning permission will generally be required for the project, and it would be advisable to consult with the planning authority at an early stage to gauge the issues that are likely to be of particular concern for the site in question. For more details see the legal section of this Guide.

Particularly in urban areas, planning authorities are likely to be especially concerned about the impact that a CHP scheme may make on local environments during the construction phase of the project. Reassurance must be offered and effective plans devised to minimised the disruption envisaged. This is particularly the case for laying under-street heat mains.

A2.4.2 Environmental assessment

Unless the CHP plant is a very large installation (with a heat output of over 300 MW) then an environmental assessment is required only if the project is likely to have significant effects on the environment because of its nature, size or location. However, in many sensitive locations the use of a thorough environmental assessment may be considered, even if it is not required by law, to supplement and reinforce a planning application.

The product of an environmental assessment – an environmental statement – is a substantial document that must:

- provide a description of the proposed development
- give data to identify and assess the main effects of the development
- describe the impact on human beings, flora, fauna, soil, water, air, climate, landscape, material assets and cultural heritage
- describe measures proposed to mitigate any effects described
- provide a non-technical summary.

Often, to support a statement, alternatives are described and impacts from these are quantified. An example for CHP schemes may be to describe the quantities of pollutants that the construction of the plant will prevent being emitted due to the inherent energy efficiency of CHP.

	Coal-fired g/kWhe	Emission controlled coalfired g/kWhe	Combined-cycle gas turbine g/kWhe	UK supply, all sources g/kWhe
CO_2	955	990	450	570
NO_x	4.34	2.9	0.5	1.76
SO_2	11.8	1.5	negligible	5.62

Note: Emission controlled coal-fired includes low NOx control and flue gas de-sulphurisation

Table A2.4 Emission indices for UK generation capacity (Source: DETR Digest of Environmental Statistics, 1997)

	Coal (2.0% sulphur) g/kWht	Heavy fuel oil (2.5% sulphur) g/kWht	Gas oil (0.3% sulphur) g/kWhc	Natural gas (no sulphur) g/kWht
CO_2	410	333	311	225
NO_x	0.78	0.79	0.26	0.22
SO_2	5.14	5.27	0.59	0.00

Note: Typical sulphur contents are given - these may vary in specific cases

Table A2.5 Typical emissions from existing boilers based on overall efficiency of 80% (gross calorific value) (Source: Refill)

	Gas turbine with waste heat boiler and back pressure steam	Boiler and back pressure steam turbine	CI engine with waste heat boiler	SI engine with waste heat boiler

	turbine Natural gas (no sulphur)	Coal (2.0% sulphur)	Heavy fuel oil (2.5% sulphur)	Natural gas (no sulphur)
Energy ratio	1.1	5.5	1.4	1.6
Emissions	**g/kWe**	**g/kWe**	**g/kWe**	**g/kWe**
CO_2	510	2700	800	500
NO_x	0.9	5.2	8-15	1.5
SO_2	Negligible	34.3	10.5	Negligible

Note: Energy ratio is the ratio of units of heat energy produced per unit electricity generated. All figures should be confirmed by power plant suppliers/manufacturers

CI = Compression ignition SI = Spark ignition

Both CI and SI engines are internal combustion (IC) engines

Table A2.6 Typical emission indices of CHP plant (Sources Refs 1,2)

A2.5 OPERATIONAL ENVIRONMENTAL IMPACTS

This section reviews the positive benefits that CHP may bring to the environment. It will therefore describe the emission mix of existing UK power plant and compare this to the heat and generation emission profile of some typical CHP installations.

A2.5.1 Emission calculations

Use of CHP instead of conventional plant will always improve energy efficiency and will reduce CO_2 emissions significantly. In order to quantify the emissions saved it is necessary to calculate:
(emissions arising from conventional plant) minus (emissions arising from a CHP plant).
It is possible to develop a worksheet to calculate the percentage savings that could be expected from a certain project. A blank example is given in table A2.7 and a worked example in table A2.8 – see case study description (A2.5.2). This type of calculation is probably best done on a spreadsheet where the calculations can be automated and many options explored.
While the use of indices is helpful in expressing the order of magnitude of pollutant emission savings, it does have its reservations. These centre on the assumptions that have been used to calculate the indices, and also the load patterns of the CHP plant. One particular problem with assessing the environmental impact of a CHP plant is the location of the emissions. In a situation where CHP-generated electricity is replacing electrical capacity, although the total pollution burden nationwide is less, the pollution burden in the district where the plant is located may increase. This may well cause difficulties in urban areas, where planning authorities are under a duty to ensure that

statutory ground level concentration limits for NO_x and SO_2 are met. In these situations advanced emission control technologies may have to be employed (see section A2.5.4). In the case where the CHP plant is being retrofitted to an existing waste-to-energy plant there is also another issue: the extraction of heat from a steam turbine will result in a reduction of electrical output and some of the environmental benefits in generating electricity from waste will be lost. Overall however, the primary energy efficiency will be increased significantly because boiler fuels for heating are displaced and reductions in CO_2 emission will therefore be achieved.

No	Description			Units
1	Electrical energy supplied by CHP plant	x		kWhe/year
2	Heat supplied by CHP plant	y		kWht/year
3	Electricity supplied by CHP plant displaces which type of central generating capacity?			
4	Emission index (from table A2.4) for CO_2	A_C		g/kWhe
5	Emission index (from table A2.4) for NO_x	A_N		g/kWhe
6	Emission index (from table A2.4) for SO_2	A_5		g/kWhe
7	Heat supplied displaces heat generated by what type of boiler plant?			
8	Emission index (from table A2.5) for CO_2	B_C		g/kWht
9	Emission index (from table A2.5) for NO_x	B_N		g/kWht
10	Emission index (from table A2.5) for SO_2	B_S		g/kWht
11	CO_2 emitted from existing plant $(x \times A_C) + (y \times B_C)$	d		g/year
12	NO_x emitted from existing plant $(x \times A_N) + (y \times B_N)$	e		g/year
13	SO_2 emitted from existing plant $(x \times A_5) + (y \times B_S)$	f		g/year
14	What type of CHP system is proposed?			
15	Emission index (from table A2.6) for CO_2	C_C		g/kWhe
16	Emission index (from table A2.6) for NO_x	C_N		g/kWhe
17	Emission index (from table A2.6) for SO_2	C_S		g/kWhe
18	CO_2 emitted from CHP plant $(x \times C_C)$	j		g/year
19	NO_x emitted from CHP plant $(x \times C_N)$	k		g/year

20	SO_2 emitted from CHP plant (x x C_S)	*l*		g/year
21	Net savings in CO_2 *(d - j)*	*p*		g/year
22	Net savings in NOx *(e - k)*	*q*		g/year
23	Net savings in SO_2 *(f- l)*	*r*		g/year
24	Percentage savings in CO_2 (100 x *(p/d))*			%
25	Percentage savings in NO_x (100 x *(q/e))*			%
26	Percentage savings in SO_2 (100 x (r/*f*))			%

Table A2.7 Example worksheet

No	Description			Units
1	Electrical energy supplied by CHP plant	*x*	2 300 000	kWhe/year
2	Heat supplied by CHP plant	*y*	3 680 000	kWht/year
3	Electricity supplied by CHP plant displaces which type of central generating capacity?		Old coal	
4	Emission index (from Table A2.4) for CO_2	A_C	955	g/kWhe
5	Emission index (from Table A2.4) for NO_X	A_N	4.34	g/kWhe
6	Emission index (from Table A2.4) for SO_2	A_S	11.8	g/kWhe
7	Heat supplied displaces heat generated by what type of boiler plant?		Natural gas	
8	Emission index (from Table A2.5) for CO_2	B_C	225	g/kWht
9	Emission index (from Table A2.5) for NO_X	B_N	0.22	g/kWht
10	Emission index (from Table A2.5) for SO_2	B_S	0	g/kWht
11	CO_2 emitted from existing plant (x x A_C) + (y x B_C)	*d*	$3.02\text{x}10^9$	g/year
12	NO_X emitted from existing plant (x x A_N) + (y x B_N)	*e*	$10.79\text{x}10^6$	g/year
13	SO_2 emitted from existing plant (x x A_S) + (y x B_S)	*f*	$27.1\text{x}10^6$	g/year
14	What type of CHP system is proposed?		SI natural gas	
15	Emission index (from Table A2.6) for CO_2	C_C	500	g/kWhe

16	Emission index (from Table A2.6) for NO_X	C_N	1.5	g/kWhe
17	Emission index (from Table A2.6) for SO_2	C_S	0	g/kWhe
18	CO2 emitted from CHP plant (*x* x Cc)	j	1.15x109	g/year
19	NO,, emitted from CHP plant (*x* x C_N)	k	3.45x106	g/year
20	SO2 emitted from CHP plant (*x* x C_S)	l	0	g/year
21	Net savings in CO_2 (d - j)	p	1.8 7x109	g/year
22	Net savings in NO_X (e - k)	q	7.34x106	g/year
23	Net savings in SO_2 (f- 1)	r	27.1x106	g/year
24	Percentage savings in CO_2 (100 x (p/d))		62	%
25	Percentage savings in NO_X (100 x (q/e))		68	%
26	Percentage savings in SO_2 (100 x (r/f))		100	%

NB It should be noted that, whereas it is often assumed (as above) that installation of CHP displaces production of electricity from coal-fired power stations, there is some level of uncertainty in this because the current Pool system of trading calls upon generating plant in ascending order of bid prices.
The value in lines 1 and 2 assume a heat:power ratio for CHP of 1.6:1

Table A2.8 Case study calculation

A2.5.2 Case study

A spark ignition natural-gas-powered CHP unit is to replace a natural-gas-fuelled central boiler plant on a housing development. 3680 MWht of heat demand and 2300 MWhe of electricity will be supplied each year; this information is shown in lines 1 and 2 of table A2.8, which illustrates the calculation using values in lines 4, 5, 6, 8, 9,10, 15, 16, 17 from tables A2.4, A2.5, A2.6.

A2.5.3 Other environmental impacts

A2.5.3. 1 Noise

All CHP systems have plant and equipment that will emit noise into the environment. This may be continuous (eg reciprocating machinery) or intermittent (eg boiler blowdown). Noise can be a statutory nuisance under the Environmental Protection Act (EPA), and local authorities will investigate any complaints. It is very likely that any planning application will specify the level of increase in background noise that would be acceptable, and this can be set very low – if not to zero. Careful design of acoustic enclosures and exhaust silencers will be required. These can add considerably to the capital cost of the project and exhaust silencers will affect plant performance adversely. It should be noted that reciprocating machinery emits more noise at low frequencies and special mounts will, for instance, be required. Gas turbine plant will require particular

treatment of air inlet ducts.

A2.5.3.2 Visual impact

The impact that a CHP plant will have on the visual amenity of an area is related to the character of existing development. Therefore design of buildings, etc should reflect, and be in sympathy with, surrounding elements, particularly in urban situations. Stacks and chimneys may be required to be of sufficient height to allow adequate dispersion of pollutants, and these may require careful attention in residential districts.

A2.5.4 Advanced emission control technologies

In situations where there is a possibility of localised pollutant concentrations exceeding statutory limits, advanced techniques can be used to help reduce NO_X and SO_2 emissions. All of these technologies add considerably to the cost of the project, but may well become increasingly necessary in installations in urban areas.

A2.5.4. I Catalytic reduction

Catalytic reduction techniques have been used widely in the U.S.A. and Japan, and some technologies have proved highly successful in reducing NO_X emissions by up to 90%. Selective reduction involves blending ammonia in the exhaust gases, which must be at 300-400°C, and passing them over a catalyst. The process must be very carefully controlled to ensure the catalyst does not become contaminated, in which case the overall efficiency of the CHP plant would fall.

A2.5.4.2 Other NO_X reduction techniques

The careful design of combustion chambers and burners can make a significant impact on the formation of NO_X in exhaust gases, as can very careful combustion control. Manufacturers' data should be used wherever possible, as there is significant variation between prime mover designs with technical improvements being made on a continuous basis. Other techniques have demonstrated the use of ammonia injected into the combustion zone – but this requires combustion temperatures of up to 1000°C in order to be successful.

A2.5.4.3 Flue gas desuiphurisation

There are well-proven wet and dry techniques for removing a large proportion of sulphur in combustion gases from processes that use fuels with a high sulphur content. Wet scrubbers use a spray of water and crushed limestone to absorb the SO_2 to create gypsum. The efficiency can be as high as 90%. Dry methods inject powdered limestone into exhaust gases, where up to 75% of SO_2 may be removed in bag filters. Again, both of these processes are extremely capital intensive, and adversely affect the performance of the plant.

A2.6 REFERENCES

[1] Environmental Aspects of Large-Scale Combined Heat and Power, Good Practice Guide 116, DETR (except for Spark-Ignition engines, see **[2]**)

[2] Information provided from Wartsila NSD UK Ltd on emissions factors indicates a range of 0.7g/kWhe to 1.3g/kWhe being achievable for the 16V255G engine. The figure given in **[1]** of 3g/kWhe does not therefore reflect current engine design; a figure of 1.5g/kWhe has been given in table A2.6 to allow for a degree of pessimism.

APPENDIX 3 INSURANCE

A3.1 INTRODUCTION

This section provides some basic guidelines on the insurance considerations. Each project will vary in complexity so it is recommended that an insurance adviser be consulted to provide assistance throughout the project.
A proactive approach to risk management will ensure the support of the insurance market in both the breadth of cover and the cost.
The appendix is in three parts:

- construction phase
- operational phase
- basic information.

In each section the risks are listed under the headings of assets, income and liabilities and the most appropriate type of policy is indicated.

A3.2 CONSTRUCTION PHASE

There are two possible approaches:

- project policy specific to the scheme, covering all parties
- reliance on the provision of cover purchased individually or carried by each party.

Choosing the right option will depend on the circumstances of the scheme and it is recommended that advice be taken on this issue at the earliest stage, together with how the contract conditions affect the insurance considerations and/or present additional risks.

RISKS AND EXPOSURES	TYPE OF POLICY
1. Assets Temporary and permanent works (including buildings, machinery, plant) in the course of construction, erection or installation and while commissioning/testing.	CONTRACTORS' ALL RISKS
Loss or damage to buildings (including weatherproofing of roofs and/or external walls) due to an inherent defect in the aforesaid.	SEE OPERATIONAL PHASE (LATENT AND INHERENT DEFECTS)
Hired plant, equipment, temporary buildings which are the responsibility/risk of the contractor(s).	CONTRACTORS' ALL RISKS
2. Income Loss of future anticipated revenue, increased cost of construction and other financial losses caused by loss or damage to the works in the course of construction, erection or installation, but prior to completion.	ADVANCED PROFITS

Loss of future anticipated revenue caused by loss or damage to buildings (including weatherproofing of roofs and/or external walls) due to an inherent defect in the aforesaid.	SEE OPERATIONAL PHASE (LATENT AND INHERENT DEFECTS)
3. Liabilities Legal liability to pay compensation for death, injury, illness or disease, other than to employees, or property damage.	PUBLIC LIABILITY
Legal liability to pay compensation to employees for death, injury, illness or disease.	EMPLOYER'S LIABILITY
A3.3 OPERATIONAL PHASE	
1. Assets Buildings owned or for which you are responsible, including landlord's fixtures and fittings and tenants' improvements, external walls, fences, gates, landscaping, car parks, outbuildings, yards, machinery bases and underground services.	PROPERTY
Contents of the buildings, and machinery, plant and equipment, trade and office furniture, fixtures and fittings.	PROPERTY
Loss or damage to buildings (including weatherproofing of roofs and/or external walls) due to an inherent defect in the aforesaid.	LATENT AND INHERENT DEFECTS
Stock and materials in trade, work completed and in progress, customers and other goods in trust.	PROPERTY
Terrorism/subsidence	OPTIONAL PROPERTY COVER
Leakage of sprinklers	PROPERTY OR SPRINKLER LEAKAGE
Steam boiler and pressure plant explosion	ENGINEERING
Accidental damage to or breakdown of computers including peripherals used in the production process or office. Also reinstatement of data, increased cost of ,working following breakdown or accidental damage.	COMPUTER
Machinery, plant and equipment hired in.	PROPERTY OR ENGINEERING
Breakdown of machinery and plant	ENGINEERING BREAKDOWN
Property while in transit within the UK	PROPERTY IN TRANSIT OR PROPERTY
Vehicles and plant and machinery, including those hired in, where Road Traffic Act cover is necessary.	MOTOR
Money at your own premises and in transit.	LOSS OF MONEY

2. Income Loss of gross revenue and additional cost of working following loss or damage to your property	BUSINESS INTERRUPTION
Loss of gross revenue and additional cost of working resulting from breakdown/failure of machinery/plant.	ENGINEERING BUSINESS INTERRUPTION
Loss of future anticipated revenue caused by loss or damage to buildings (including weatherproofing of roofs and/or external walls) due to an inherent defect in the aforesaid.	LATENT AND INHERENT DEFECTS
Loss of gross revenue and additional cost of working following loss or damage at suppliers' or customers' premises and failure of public utilities	BUSINESS INTERRUPTION AND ENGINEERING BUSINESS INTERRUPTION EXTENSIONS
Reinstatement of data, increased cost of working etc. Following computer breakdown or accidental damage.	COMPUTER BUSINESS INTERRUPTION
Unrecoverable outstanding business following loss of or damage to business records	BOOK DEBTS AND COMPUTER BOOK DEBTS
Loss due to insolvency or failure to pay accounts due to default of customers to whom goods or services have been delivered or work done on credit terms.	CREDIT
3. Liabilities Legal liability to pay compensation for death, injury, illness or disease, other than to employees, or property damage arising from the business activities, the products/services provided or the premises occupied.	PUBLIC/PRODUCTS LIABILITY
Legal liability to pay compensation for death, injury, illness or disease to employees arising from the business activities.	EMPLOYERS' LIABILITY
Legal liability to pay compensation arising from pollution (other than sudden and accidental) - first and third party.	ENVIRONMENTAL IMPAIRMENT
Liability of directors and officers	DIRECTORS' AND OFFICERS' LIABILITY
Legal liability to pay compensation arising out of libel or slander.	PUBLIC LIABILITY OR PROFESSIONAL INDEMNITY
Legal expenses of the company in defending or mounting an action.	COMMERCIAL LEGAL EXPENSES
4. Statutory Inspection Inspection of machinery, plant and equipment where periodic inspection is required by legislation or is advisable as good risk-management practice.	ENGINEERING INSPECTION
5. Some other considerations	

Death, injury and disablement benefits for key and/or all directors/employees following accident.	GROUP PERSONAL ACCIDENT COVER
Theft by employees (staff honesty).	FIDELITY GUARANTEE
Personal accident, medical and emergency expenses and travel assistance for employees travelling abroad.	BUSINESS TRAVEL

A3.4 BASIC INFORMATION

Below is a list of the basic information likely to be required by insurers. While individual circumstances may require more detail, the points listed will provide a sound basis for discussion with insurers.

A3.4.1 Information specific to construction

- Construction/erection/installation method statement.
- Breakdown in construction/erection/installation costs split between civil and mechanical/electrical.
- For major items of machinery/plant; installation time-scales; manufacturing time-scales.
- Site layout, plant layout.
- Bar chart showing progression of work.
- Commissioning/testing periods.

A3.4.2 Common aspects

A3.4.2. I General

- Consideration of who needs to be covered ('The Insured') at each stage and under each type of policy.
- A description of the scheme, with plans and schematics showing processes to be carried out.
- Construction/heating and use of buildings.
- Risk-management structure and responsibilities.

A3.4.2.2 Assets

Material damage

- Schedule of buildings owned by or for which the company is responsible, showing location, age, reinstatement/replacement value and usage.
- Description and value of tenants' improvements (where leased property), fixtures and fittings including sprinkler installation.

- Value of external features, eg yards, perimeter walls, gates and fences plus landscaping, outbuildings and utilities.
- Schedule, for each location, of machinery, plant and equipment, trade and office furniture, fixtures and fittings (including electronic office equipment).
- Value of non-ferrous metal/precious metals at each location.
- Whether cover is required for subsidence/terrorism.
- What inflation provisions are required.

EngIneering

- Details and specifications for steam boilers, power generation engines/turbines and any other major machinery and plant.
- Type of hired-in plant, estimated maximum value of any one item, estimated annual hiring charges, contract conditions applying and a sum insured for continuing hire charges liability.

Motor

- Schedule of vehicles and plant if licensed for road use.
- Cover required, eg comprehensive or third party, fire and theft, or third party only.
- Drivers' particulars (eg age, driving experience, convictions and accident history).

Computers and peripheral equipment

- Description including make, manufacturer, model number and new replacement value.
- Whether both damage and breakdown cover is required.
- What they are used for, eg accounting, production, etc.
- Situation, eg shop floor, customer's office or computer suite.
- Security of hardware and software.
- Whether a maintenance contract is in force and whether it provides free parts and labour and a guaranteed call-out within 24 hours.

Money

- Estimated annual carryings:
  - to and from bank/post office.
  - other carryings, eg contract sites/other premises etc.
- Any one loss limit.
- Where cover is to apply, ie on premises during business hours, out of business hours, in transit or safe, etc.

- Details of safe, and limits required.
- Method of conveyance – security company, employee, etc.
- Security precautions taken – escorts, routing, timing, security cases etc.
- Personal accident assault benefits required.

A3.4.2.3 Income

Business interruption

- Whether cover to be the same as that for property.
- Anticipated gross revenue – provide calculation.
- Uninsured working expenses, ie those expenses not incurred/avoided in the event of loss/damage, such as consumables.
- Percentage of gross revenue reliant on individual major customers or suppliers.
- What penalties/liquidated damages could be incurred for failure to supply.
- Details of any other income.
- Inflation provision required.
- Maximum indemnity period required.
- Whether cover is required for terrorism/subsidence.

Engineering business interruption

- Anticipated loss of gross revenue following damage or breakdown of major items of plant.
- Where major items of plant fit into the production process and the contribution to the company's gross revenue.
- Maximum indemnity period required.
- Whether utilities (gas, electricity, water) are to be covered.
- Back-up facilities (if any) in the event of loss/damage.

Computers

- Assessment of the impact that the loss of the computer system would have on the gross revenue.
- Whether a maintenance contract is in force, and if it provides free parts and labour and a guaranteed call-out within 24 hours.
- Value for reinstatement of data.
- Value for increased cost of working.

- What indemnity period is required.

Book debts

- Maximum value of outstanding debit balances.
- How are accounts rendered.
- Location where records are kept and how they are stored.
- Location where duplicate records are kept.

A3.4.2.4 Liabilities

Employers' and public/products liability

- Estimated wages (split between clerical and manual) and turnover.
- Limits of indemnity required.
- Description of processes: including machinery used, materials brought in, hazardous substances used or stored, hazardous processes, waste produced and disposal methods.
- Details of work carried out at customers' or other third party's premises and whether it involves the application of heat.
- Details of any liability assumed under contract (including copy of actual contract conditions).

Directors' and officers' liability

- Who is to be covered, including names, positions held and experience.
- Limit of indemnity required.
- Accounting projections.

A3.4.2.5 Other

Fidelity guarantee (staff honesty)

- Limit of indemnity required per employee, per loss and in the year.
- Number of employees.
- Estimated wages/salaries paid to all employees, split between those responsible for cash, finances and stock, and those not.

Group personal accident

- Employees to be covered.
- Benefits required.
- Estimated earnings.

- Cover required, ie 24 hour; occupational only.
- Travel abroad? Pattern of travel.

APPENDIX 4 HEALTH AND SAFETY

A4.1 HEALTH AND SAFETY AT WORK ACT (1974)

The single most important health and safety legislation that operators of CHP plants have to consider when formulating their health and safety policy for a scheme is the Health and Safety at Work Act (1974). This document covers all work activities and places a duty of care not only on employers, but also on suppliers, employees, persons in charge of premises and the self-employed.

It emphasises the need for clearly defined safety arrangements by the organisation. Anyone planning to operate a CHP scheme must ensure that they have within their organisation the ability to understand fully the relevant parts of the Act and be able to implement its requirements.

For example, section 2(1) of the Act states: 'It shall be the duty of every employer to ensure, so far as is reasonably practical, the heath, safety or welfare at work for all his employees'.

This duty includes the provision and maintenance so far as is reasonably practicable:

- safe plant and systems of work
- necessary information, instruction, training and supervision
- safe handling, storage and transportation of articles and substances
- adequate maintenance of safe working place, with safe access and egress
- a safe and healthy working environment.
- Management of Health and Safety at Work Regulations 1992
- Manual Handling Operations Regulations 1982
- Testing of Portable Electrical Equipment (Electricity at Work Regulations 1989)
- Pressure Systems and Transportable Gas Container Regulations 1989
- Construction Design and Management (CDM) Regulations 1994
- New Roads and Street Works Act, 1991
- Duty of Care to the Public and Employees (Environmental Protection Act 1990)
- Personal Protective Equipment Regulations 1992
- Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 1995
- Provision and Use of Work Equipment Regulations 1992
- Confined Spaces Regulations 1997

- Noise at Work Regulations 1989
- Gas Safety (Installation and Use) Regulations 1994 11
- Supply of Machinery (Safety) Regulations 1992
- Workplace (Health, Safety and Welfare) Regulations 1992

CHP plant supplied in the European Economic Area (EEA) is subject to the Supply of Machinery (Safety) Regulations 1992. This requires a supplier to address a fairly lengthy list of essential safety requirements (ESRs). If the machinery complies, then it is CE marked and a certificate of conformity is issued. This should be a valuable aid to the customer.
All of the above are of vital importance to operators of CHP.
It then proceeds to explain in other sections the duties of employees, designers, manufacturers, suppliers, importers, etc and the powers of the Health and Safety Executive as defined in the act.

A4.2 OTHER REGULATIONS

Since its enactment many other regulations have followed, all of which have had an impact upon the operations of CHP schemes, these include:

- Control of Substances Hazardous to Health (COSHH) 1994

A4.3 HEALTH AND SAFETY POLICY

Carrying out risk assessment and setting up a Health and Safety Policy for a CHP scheme can be a complicated exercise and will depend upon the size and complexity of the scheme. A CHP scheme can vary greatly, from mass-burn incineration with power generation together with commercial supplies, and community heating, to a single boiler supplying small blocks of dwellings with heating and hot water.
The development of a Health and Safety Policy depends largely on the size of the company as to whether it is carried out using in-house resources or by an independent safety consultancy, which may be the preferred route of a smaller organisation.
Whichever route is finally chosen, it is important that a health and safety policy is in force before operation of the scheme begins.
It should be the aim of any company to ensure safe systems of work; this can usually be done with the help of a safety procedure manual.

A4.4 THE BASIC REQUIREMENTS OF HEALTH AND SAFETY

A4.4.1 Safety policy (where more than five people are employed)

- Prepare a written statement of general health and safety policy.
- Set down the arrangements for carrying out the policy, ie who is responsible for what.
- Revise and update as necessary.
- Bring the policy and arrangements to the notice of all employees.

A4.4.2 Safety representatives and safety committees

The act provides for recognised trade unions to appoint safety representatives who have functions prescribed by the Safety Representatives and Committees Regulations 1977 (Note: s 2(5) repealed by Employment Protection Act).
An employer must ensure the following.

Consultation

- Consult with safety representatives on the arrangements for cooperation on safety measures.
- Consult with safety representatives on monitoring safety measures.
- Establish a safety committee when requested by two or more trade union-appointed safety representatives.

Provision of safe systems of work

This will require drawing up a site operating procedure, after carrying out risk assessments and evaluation of the tasks being performed.

Workplace (Health, Safety and Welfare) regulations 1992

These require that the place of work is assessed to ensure that it is safe. Particular attention should be paid to:

- floors
- ventilation
- heating
- traffic movement and routes
- sanitation and washing facilities.

Monitoring of safety performance

This should include regularly carrying out:

- safety audits
- safety surveys
- safety inspections.

Also, reviewing accidents is important to find the root cause, examining procedures and modifying these to see if they can be improved to stop accidents recurring.

Electrical risk

Safeguards should be implemented to prevent access to live electrical components.

Lifting equipment

A system of inspection also needs to be put into place to ensure that all statutory requirements are fulfilled. This applies to:

- cranes
- chains
- slings and ropes
- passenger and goods lifts
- shackles.

Statutory inspection of boilers

This should be carried out in compliance with the Pressure Systems and Transportable Gas Containers Regulations, 1989.

Road transport

The traffic routes on site need to be carefully considered and a traffic control system implemented to minimise dangers to employees and the general public.

Provision and use of work equipment regulations 1992

The CHP plant itself is subject to these regulations. It also covers equipment, new and second-hand, such as:

- ladders
- drills
- hand tools
- scaffolding
- fork-lift trucks
- soldering irons
- welders.

It states that dangerous parts are to be guarded as far as is practicable, and equipment should:

- have appropriate controls
- have clear identification, and must be suitable by design, construction or adaptation for the work for which it was intended
- be properly maintained
- be operated only by employees who have been adequately instructed and trained.

Noise

Noise levels of plant and of the working environment should be restricted in compliance with the Noise at Work Regulations, 1989. Plant should, if possible, be sited so that no screening of noise is required.

A4.5 NEW ROADS AND STREET WORKS ACT (1991)

Part of this Act is to enhance the safety of operatives who are engaged in civil works activities by ensuring that they are supervised by a trained and qualified person. This person also has to ensure that adequate precautions are taken regarding pedestrian and traffic management and the works do not interfere with other utilities, and reinstatement of the works is carried out correctly.

A4.6 REFERENCES

The above sections are not intended to be a definitive and exhaustive list of requirements for health and safety but provide a guide to the more important requirements of safety on a CHP scheme.

The following guidance on the operation of CHP plant also contains relevant information: Guidelines for the Preparation of Technical Specifications for Small Scale (<1 MWe)

Combined Heat and Power (CHP) Installations, Combined Heat and Power Association, 1996.
An acoustic enclosure may well be required. However, this means that there is a confined space in which a flammable gas or other volatile fuel is being conveyed and used. Precautionary measures will therefore be necessary.

APPENDIX 5 EXISTING DISTRICT HEATING SYSTEMS - RETENTION, REFURBISHMENT OR REMOVAL

A5.1 INTRODUCTION

Problems have been experienced with the operation and maintenance of many district/group heating schemes in the UK, and several authorities have been involved in analysing schemes to establish more precisely the nature of faults and difficulties. Schemes investigated have ranged in size from as small as 30 dwellings through systems serving 150-300 and up to 2000 dwellings.
Detailed evaluation of individual sites indicates that faults were technically soluble and capable of correction. Many problems experienced were due to the fact that while financial and engineering decisions taken at the time of the original design and installation — in the late 1960s or early 1970s – were, and can be proved to have been, reasonable in the light of information available at that time, they were subsequently adversely affected by external influences such as the oil price crisis, the development of natural gas, and the need for energy conservation.
Many schemes were also halted, or substantially reduced in scale, during the installation stage with resultant detrimental effects on operational efficiencies and economies of scale.

A5.2 EVALUATING THE OPTIONS

The options available to local authorities include retention, refurbishment/upgrading or removal, and in order that a balanced judgement can be made it is essential that before large-scale capital investment is made in any existing or future scheme, each application is evaluated in both technical and economic terms over the expected useful life of the system. Such technical and economic studies should preferably contain reference to any large-scale capital expenditure involved on the basis of public sector investment appraisal methods employing approved NPV/IRR techniques, acceptable to economists in both local and central government. It is also essential in evaluating the nature of possible future schemes that these should also be approached on the same basis. Any overall analysis should include reference to the following factors:

- operational efficiencies and costs per kWh
- accounting procedures and cost assessments to tenants
- administrative problems associated with housing management
- levels of account ‘arrears’ and cost collection problems
- system breakdowns and condition of boiler plant, underground mains and dwelling internals
- metering implications with regard to future operational costs and efficiencies

- cost quantification of unmetered losses and identification of ‘single pipe loop’ systems
- cost quantification of any water losses and investigation into water treatment and make-up water meters
- financial effects resulting from systems operating below design capability
- effects of tenant energy conservation on plant loads and efficiencies
- investigation into the effects of the provision of additional tenant/landlord controls (programmers and 2 or 3 port valves, etc)
- central plant efficiencies and electronic meters to measure heat ‘at the boilerhouse wall’
- evaluation of alternative fuels/refuse-derived fuel (RDF)/CHP, refuse incineration, etc
- possible introduction of pre-payment heat controllers
- existing and future maintenance procedures
- economic appraisal of existing systems in the long term
- availability of resources and possible use of private sector finance.

While several of the items listed may be considered contentious in certain instances it is essential that the implications of both present and future actions should be fully appreciated.

A5.3 INVESTMENT ANALYSIS

In evaluations of this nature the options include various strategies from merely returning the heating system to a viable operating state through to a situation whereby full financial control can be maintained over the operation of the system and the final option considers removal of the existing system and the provision of suitable replacement systems which would not be based on the principle of district heating.

A common feature of each option is to determine the varying life expectancy of the equipment and components of each of the systems contained within the options, and from this it is possible to determine the overall useful life of each option. The assessment of such life expectancies is an engineering judgement and is based on data issued by the BRE, BSRIA, etc. However, it is clear that to maintain a viable operating system on an ongoing basis, the capital cost profile incurred at the initial refurbishment stage will recur at some point in the future when the system requires a second and subsequent refurbishment(s) and it is important to reflect this in the investment appraisal.

It is important that the scheme owner be fully aware of the basis on which the analysis has been prepared. This will prevent misunderstandings arising because of the selection of an appraisal review period which may not necessarily reflect the refurbishment costs for each option in the particular year in which they will ultimately be incurred. However, extending the review period to cover the whole of the major cost cycle resolves this presentational difficulty and this is the approach adopted in the economic appraisal procedure described.

The scheme owner should appreciate fully the recurring nature of the respective cost cycles if they wish to maintain an ongoing viable system, and consideration can be given to the development of a separate fund to be set aside during the initial life expectancy of the equipment to provide for its eventual replacement.

It could be suggested that where the review period is less than the full cycle of any major component part of the system, this could lead to confusion and misunderstanding in interpreting the financial implications. For example, it might be suggested that credits should be made in calculations in respect of the unexpired life element of any particular component of the system at the end of the review period. This would, however, undoubtedly cause confusion since it appears unlikely that any sum so credited would be realised should the system be terminated at that time and therefore the capital cost of operating the system for the review period would be in excess of the sum arrived at by that principle.

Alternative calculations can also be made on the basis of lease rentals for the review period, but this may be open to confusion because it may not recognise the ongoing leasing cost commitment for the unexpired period of asset life on items such as mains and meters, etc, beyond the review period. Obviously, an ongoing liability would be present even if the system were terminated at that point.

It is essential that the presentation of investment appraisal information clearly demonstrates the capital costs of providing a viable and ongoing system for each of the options under consideration. It is clearly important to emphasise the recurring nature of the capital costs involved and the presentation of information is somewhat complicated by the differing useful lives of the major component elements within the systems. A cycle of cost based on the major asset life expectancy must, therefore, be established in order to assist in determining the true cost of providing an ongoing long-term system.

In conclusion, it is important to appreciate that certain technically feasible options may be eliminated by political, legal or financial constraints.

GLOSSARY

Absorption chiller (ABS)

A type of refrigeration plant that can provide cooling from low-grade heat and is therefore ideally suited to combining with CH/CHP systems.

Approach temperature

The approach temperature of a heat exchanger is the temperature difference between the ingoing hot fluid, from which heat is being recovered, and the outgoing warmed fluid, to which it is transferring its heat. The closer these temperatures become the more efficient the heat exchange process.

Auxiliary firing

The addition of extra fuel into the exhaust gases of a turbine to provide an increase in heat output is called auxiliary firing. This uses the preheated excess oxygen in the exhaust gas from the turbine and provides extra heat at high efficiency. This is ideally suited for meeting peak heat demands.

Back-pressure steam turbine

A back-pressure steam turbine relies on the expansion of the steam within the turbine – which is driving the alternator – without condensing the steam. The exhausted steam is then used to provide the heat for the hot water distribution system. This is a simple system but comparatively inefficient.

Base load

The level of demand, for heat or electricity, that exists for the majority of the operating period. The demand will rarely be less than this base load. This load should be met from the lowest cost sources.

Building energy management system (BEMS)

A computer with suitable software can be used to control the operation of boilers, valves, lighting and other plant remotely. The use of a computer enables sophisticated control strategies to be programmed in, operators to be alerted to problems, and the operation of the system to be recorded.

Cathodic protection

To avoid corrosion an electrical potential is applied between the components of the system. This prevents corrosion caused by the presence of materials of different electrode potentials.

Cavitation

Cavitation is caused when the pressure of a fluid in a system is reduced below its vapour pressure arid vapour bubbles are formed. This produces noise, reduces the pumping efficiency and can cause mechanical damage to the components of the system, especially at the pump or valve where the cavitation is taking place.

Combined cycle

The combination of a number of power generation methods to extract the most energy from the fuel. Typically, the exhaust from a gas turbine, driving a generator, is used to generate steam which then drives a steam turbine, also driving a generator. This increases the efficiency of electricity generation to about 50%.

Combined heat and power (CHP)

Combined heat and power systems provide simultaneous heat and power by the combustion of a fossil fuel. The electrical power is provided by a prime mover and the heat is recovered from the exhausted combustion products – possibly with some additional supply – this provides a significant reduction in primary energy use.

Community heating (CH)

Providing heating to a number of buildings or dwellings from a central source is referred to as community heating. It offers the opportunity for energy efficiency and affordable warmth.

Constant temperature circuits

The parts of the heating distribution system which are maintained at a constant temperature suitable for providing domestic hot water or for heating systems which need a fixed temperature, rather than a temperature which varies with the external temperature — see weather compensation.

Demand diversity

The demand diversity is a measure of how much of the potential connected load is experienced as an actual load at a given time. The actual definition is 'the peak demand at the central heat supply source divided by the sum of the individual heat demands.' A factor of between 0.8 and 0.95 is normal for space heating systems. A similar concept also exists for the connected electrical load.

Direct connection

Direct connection is the use of the community heating system within the dwelling spaces directly, without the use of an intervening heat exchanger. Where appropriate this is a low-cost method of construction and is mainly suitable for small and local CH systems.

Discounted cash flow

The analysis of cash flow by analysing the value of money through a period of time and with a given interest rate.

District heating (DH)

District heating is synonymous with community heating and is the term widely used throughout Europe.

Energy services

Energy services is the consideration of the supply of energy to a site in terms of what functions the energy provides. Energy services deals more with the outcomes of energy use, heat, light and power for example, rather than simply supplying gas or electricity.

Environment Agency

The UK Environment Agency, created in the Environment Act, 1995, took over the functions of Her Majesty's Inspectorate of Pollution (HMIP), the National Rivers Authority (NRA) and the waste regulation functions of local authorities, in April 1996. It regulates emissions to air, water and land to achieve the standards set by government, and is responsible for enforcing those standards. The Environment Agency covers England and Wales; the Scottish Environmental Protection Agency and the Environment and Heritage Service (Northern Ireland) cover Scotland and Northern Ireland respectively.

Environmental Impact Assessment (EIA)

An EIA provides detailed information on the effects that a development will have on the environment. It describes the impact on human beings, flora, fauna, soil, water, air, climate, landscape, material assets and cultural heritage. Often, to support an application, the impacts of alternatives are also presented.

Extraction-condensing steam turbines

An extraction steam turbine system is one which includes a turbine which exhausts the steam to a lower than atmospheric pressure. This increases the efficiency of the generation but increases the cost and complexity of the plant.

Fibre optic system

The use of fibre optics for transmitting digital data such as heat-meter readings. They are ideal for reading meters from outside a dwelling but have restrictions on length of transmission.

Flashing

Flashing is the term used to describe the evaporation of the working fluid in the evaporator of an absorption chiller. The heat required for the evaporation to take place is extracted from the chilled water and thereby provides the cooling which is required.

Fluidised bed combustion

The application of fluidised bed techniques to the combustion of coal. Blowing combustion air up through a layer of pulverised coal supports the weight of the coal and maintains it in an almost fluid state. The combustion process then takes place very efficiently.

Full life-cycle costing

The costing of a project over the whole life of the project including the maintenance and dismantling.

Hard-wired systems

A hard-wired system is one in which data collection requires the individual meters to be directly connected to the central computer by a dedicated wiring system.

Index circuit

The index circuit is that part of the distribution system which has a controlling influence on the design. It is usually the pipeline supplying the most remote part of the system and has the greatest resistance to flow. Because of this, attention must be paid to correctly sizing this section of the system.

Index circuit reference consumer

The index consumer is the consumer on the index circuit.

Indirect connection

The supply of heat from the CH system by means of an intermediate system of heat exchangers. This type of system isolates the CH distribution network from the heating systems of the individual dwellings. It allows a more secure and flexible system for the CH supplier.

Instantaneous heat exchanger

A system in which the heat is transferred as it is required rather than diverted into a storage system for use later. It reduces the inefficiency associated with storing tanks of hot water.

Integrated pollution control (IPC)

IPC considers the discharges of a process to air, water and land, with a view to minimising the impact of the process on the environment as a whole. It aims to apply the best available techniques not entailing excessive cost (BATNEEC) to minimise the release of pollutants and to render harmless any that are released. IPC is administered by the Environment Agency (or Scottish Environmental Protection Agency).

Internal rate of return (IRR)

The rate of return on an investment which is required to ensure the project is financially viable. By definition it is the test discount rate that results in a net present value of zero.

Load profiles

The way in which the thermal or electrical load on the system varies with time. This can be seen as either the load demand of an individual user, or set of users, or the load profile as seen by the supply system. The initial feasibility study needs to address these carefully to obtain the most appropriate match.

Mains-borne system

The use of the existing electrical mains distribution system to carry data and control signals. Individual meter installations can be identified and read over the existing mains cabling without the need to make separate connections as in a hard-wired system.

Moisture detection system

A system for detecting the moisture level in the insulation of pre-insulated piping systems – necessary to provide early warning of failure of the insulation.

Net present value (NPV)

Provides a way of summarizing the initial and future costs and income associated with a venture in terms of today's value of money.

Peak load

The peak load is the maximum demand for heat or electricity that occurs in any one hour in a year.

Planned preventative maintenance (PPM)

PPM is the methodical servicing of plant at regular intervals in order to maintain the system's performance. It reduces the incidence of breakdowns and prolongs plant life.

Plate heat exchanger

A heat exchanger allows heat to transfer from one fluid to another without them coming into contact with each other. In a plate heat exchanger the fluids are pumped in opposite directions on either side of a heat conducting plate.

Pool membership

The Pool is the mechanism by which electricity is sold and bought. It is operated by Energy Settlements and Information Services Limited and Energy Pool Funds Administration Limited. Both of these organisations charge fees for belonging to the pool. Belonging to the Pool generally means all supplies must be sold to the Pool at its Purchase Price.

Pre-insulated all plastic pipe

For low temperature networks operating at up to 60^{o}C and 6 bar pre-insulated all-plastic pipe is an appropriate choice.

Pre-insulated bonded pipe

This pipe system includes a steel carrier pipe and hence will resist pressures of 16 bar and operate at temperatures of up to 120^{o}C.

Primary energy sources

Primary energy sources are coal, gas, oil, wind, etc. The energy in these sources may be converted (into heat, electricity, motion, etc) with varying efficiency. These secondary 'sources' of energy are often the ones consumers actually use, but the environmental impact of their use depends on the type and amount of primary energy used to make them.

Prime mover

In current CHP plant the electricity is produced by mechanically rotating a generator. The prime mover, a turbine or engine, provides this rotational power.

Public Electricity Supplier (PES)

The fifteen regional electricity companies (RECs) of England and Wales, the two Scottish electricity companies and Northern Ireland Electricity.

Radiation-shielding gas

Most of the atmosphere's ozone lies in a band between 15-50 km above the surface of the earth. Ozone has the property of absorbing ultra violet radiation from the sun, becoming warm in the process. In this way, living organisms on earth are partially shielded from the harmful effects of UV light.

Rebalancing

When alterations are made to the flow requirements of a system it needs to be

rebalanced, in order that the correct flow relationships are retained, since changes to flows through one part of the system can have a detrimental effect on other parts of the system.

Return temperature

The return temperature in a heating circuit is the temperature at which the heat transfer fluid (water) returns to the heating plant after passing through the system. It is important in terms of determining the efficiency of the system as a whole. Generally the lower the return temperature the more efficient the system.

Second tier

A second tier supplier is a supplier of electricity other than the host PES.

Standard Assessment Procedure (SAP)

Standard Assessment Procedure is the government's standard system for home energy rating – an expression of a dwelling's energy efficiency. It is a number between 1 and 100 (higher is better). SAP ratings are calculated mathematically by modelling the heat provision and heat flows in a dwelling.

Static pressure

The static pressure in a system of pipework is the pressure that exists when there is no movement of the fluid in the pipework. The pressure will be greatest at the lowest point in the system, by virtue of the weight of fluid above. Systems need to be pressurised to avoid cavitation and other problems.

Statutory nuisance

A statutory nuisance is one that is specifically defined in law (Part III of the Environmental Protection Act gives relevant details). Examples are: atmospheric pollution, offensive trade smells, water contamination, noise. A local authority may serve an abatement notice and prosecute.

Test discount rate

The rate of interest assumed within a discounted cash flow appraisal.

Thermal storage

Storage of heat, typically, in an insulated tank as hot water to provide a buffer against peak demand. The water may be pressurised to allow it to be kept at a higher temperature.

Three-part tariff

A three-part tariff is made up of three charging elements: a connection charge; a standing charge; and a unit charge for the energy used.

Topographic variation

Variations in the height of the systems, as a result of the geography of the site or the height of the buildings, need to be taken into account in calculating pressures within the distribution pipework.

Trend monitoring

Important parameters should be monitored regularly to establish if there are any trends which would imply a change of performance which may lead to decreased efficiency.

Two-part tariff

A two-part tariff is made up of two charging elements, a connection charge and a

standing charge. This can be used with unmetered schemes.

Variable flow system

The heat load that must be met by the CH system changes by as much as 12:1. Providing a variable flow system can accommodate this changing heat load and can also increase the seasonal efficiency of the system. It can also be beneficial for other components within the system.

Variable speed control

By varying the speed of pumps the flexibility of the system is increased and the efficiency improved. It also increases the life expectancy of the pumps and motors by reducing their loading. A combination of fixed and variable speed pumps can be used to reduce the extra cost of the variable speed system.

Weather compensated system

When the air temperatures increases, the demand for heat reduces and the demand can be satisfied with water supplied at a lower temperature. Lowering the temperature of the supply reduces heat loss rates (from pipework) and can increase efficiency overall. Such a system is said to be weather-compensated.

LIST OF ACRONYMS

ABS	Absorption — as in absorption chiller
AES	Association of Energy Suppliers
BATNEEC	In a process, BATNEEC is expected to be used to prevent or minimise releases of prescribed substances, and to render harmless any that are released. Where IPC applies, and a process releases substances to more than one environmental medium, the Best Practicable Environmental Option may be selected to minimise the pollution which may be released to the environment as a whole.
BEMS	Building energy management system A computer with suitable software can be used to control the operation of boilers, valves, lighting and other plant remotely. The use of a computer enables sophisticated control strategies to be programmed in, operators to be alerted to problems, and the operation of the system to be recorded.
BRE	Building Research Establishment Ltd
BRECSU	Building Research Energy Conservation Support Unit
BSRIA	Building Services Research and Information Association

CCM	Centralised Control and Monitoring System
CDM	Construction Design and Management Regulations (1994)
CH	Community heating Community heating is where a number of buildings or dwellings are heated from a central source.
CHP	Combined heat and power
CHPA	Combined Heat and Power Association
COSHH	Control of Substances Hazardous to Health
DBFO	Design Build Finance Operate
DGES	Director General of Electricity Supply
DH	District heating In most other countries community heat is known as district heating.
DHW	Domestic hot water
EIA	Environmental Impact Assessment
ERDF	European Regional Development Fund
ESIS	Energy Settlements and Information Services Ltd
ETSU	Energy Technology Support Unit
HDPE	High-density polyethylene insulation
IC	Internal combustion
IPC	Integrated pollution control IPC considers the discharges of a process to air, water and land, with a view to minimising the impact of the process on the environment as a whole. It aims to apply the best available techniques not entailing excessive cost (BATNEEC) to minimise the release of pollutants and to render harmless any that are released. IPC is administered by the Environment Agency (for England and Wales), the Scottish Environmental Protection Agency or the Environment and Heritage Service (for Northern Ireland).
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal rate of return
LAPC	Local Air Pollution Control
LV	Low voltage
MST	Main station
MTHW	Medium temperature hot water
MWe	Megawatts electrical

MWt	Megawatts thermal Power may be produced as electricity (MWe) or heat (MWt). Similarly, energy (Power x Time) is denoted MWhe or MWht (Megawatt hours electrical, or thermal).
NFFO	Non Fossil-Fuel Obligation
NGC	National Grid Company
NOx	Nitrogen oxides Nitrogen can combine with oxygen in different amounts, eg Nitric oxide (NO), Nitrogen dioxide (NO2). NO,, refers to the whole family of oxides.
NPV	Net Present Value
ODP	Ozone depleting potential
OFFER	Office of Electricity Regulation
PE	Polyethylene
PES	Public Electricity Supplier
PFI	Private Finance Initiative
PPG	Planning Policy Guidance
PPM	Planned Preventive Maintenance
PPP	Public/Private Partnerships
PSA	Pooling and Settlement Agreement
PT100	Platinum Resistance Thermometer A standard temperature sensor made of platinum wire whose electrical resistance varies with temperature. It has a resistance of 100 ohms at 0°C.
PUR	Polyurethane insulation
REC	Regional Electricity Company
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations
SAP	Standard Assessment Procedure
SCADA	Supervisory, Control And Data Acquisition (system)
SOS	Secretary of State
SPC	Special Purpose Company
SST	Substation
STOD	Seasonal Time Of Day A tariff for purchasing electricity where the cost/kWh depends on the time of year and the time of day.
TRV	Thermostatic radiator valve A TRV is a valve that varies the rate of flow of hot water to a radiator according to the surrounding air temperature.

UNECE	United Nations Economic Commission for Europe

11 Amended by two amendments in 1996 and currently subject to consultation on a new set of revised and consolidated regulations.